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United States Department of Agriculture
Weather Bureau :: Washington, D. C., 1930

Instructions for Making Aerological Observations

Circular P :: :: :: Aerological Division

W. B. No. 1022

UNITED STATES
DEPARTMENT OF AGRICULTURE
WEATHER BUREAU

INSTRUCTIONS FOR MAKING AEROLOGICAL OBSERVATIONS

BY MEANS OF

KITES, AIRPLANES, SOUNDING BALLOONS
LIMITED-HEIGHT SOUNDING BALLOONS
FREE-RISING CAPTIVE BALLOONS
CEILING BALLOONS

◆

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INSTRUCTIONS FOR MAKING AEROLOGICAL OBSERVATIONS

BY MEANS OF KITES, AIRPLANES, SOUNDING BALLOONS, LIMITED-HEIGHT SOUNDING BALLOONS, FREE-RISING CAPTIVE BALLOONS, AND CEILING BALLOONS

The following instructions will supersede those contained in W. B. 740, Instructions for Aerological Observers (1921), and include all methods used by the Weather Bureau for making aerological observations except pilot balloons, the latter instructions being contained in Weather Bureau Circular O (1928).

KITES

I. SELECTION AND ESTABLISHMENT OF A KITE STATION

1. Sites for kite stations must be chosen with considerable care. The country surrounding a kite station should be as free as possible from forested tracts, lakes, marshes, rivers, etc.; also, from towns, steam and electric railways, and high-tension power lines. In as much as free-air winds in this country blow for the most part from some westerly direction, it is essential that there should be as few as possible of the undesirable features above mentioned on the east side of the station. Fairly good roads are necessary in order that kites that have broken away may be readily recovered.

2. In many respects kite flying can be carried on most effectively if the station is completely isolated, so far as centers of population are concerned, but, on the other hand, difficulties of transportation, of procuring power and lights, and of providing good living conditions for the men render such a location inadvisable. As a compromise the Weather Bureau therefore selects sites with open country to the east, but with a small town (1,000 to 2,000 population) approximately 1 km. to the west. The plot used as a kite field is usually square and contains 40 acres of land, as nearly level as possible, cleared of trees, stumps, etc., and surrounded by a sufficiently strong fence to keep out live stock.

3. In case there are telegraph, telephone, or high-tension lines within a distance of 2 or 3 kms. to the north, east, or south, an extra "guard" wire is installed about 1 foot above the service wires. Power and lights are furnished from the town plant to the station by means of underground circuits. All buildings, except the reel house, and all surface instrumental equipment are located in such part of the western side of the field as is most readily accessible from the town.

4. The instrument shelter, wind tower, etc., are installed in accordance with instructions issued by the Instrument Division. Figure 1 shows the customary arrangement of buildings and instrumental equipment, as well as the location of the kite field with respect to the adjacent town.

5. The geographic coordinates of the stations are determined in the same way as for all other Weather Bureau stations. Latitude and longitude can be found for many places in bulletins of the Geological Survey, Lippincott's Gazetteer, and other publications. The data from these sources are used, after verification as to their accuracy by reference to a recent issue of Rand McNally & Co.'s Atlas. When there are no published data, the latitude and longitude, as shown by the station's location in this atlas, are used. Altitude is determined by running a line of levels from the nearest "bench mark." The height of the barometer cistern is taken as the

official station altitude above sea level. The methods of determining true meridian are described in Instructions for Making Pilot Balloon Observations, Weather Bureau, Circular O, 1928. As soon as the cardinal points are established, white posts are placed around the outer portion of the kite field, exactly north, northeast, east, etc., of the reel house, in order that wind direction, both at the surface and in the free air, may be readily determined.

6. The main building is of frame construction, one and one-half stories high, and is used for office quarters, carpenter shop, and kite storage. It is 26 ft. wide, 48 ft. long, and approximately 24½ ft. from the ground to the peak of the roof. The dimensions of the office and computing room are 25 by 14 ft.; of the carpenter shop, 25 by 12 ft.; and of the kite-storage room, 25 by 20 ft.—all inside measure. An attic provides additional room for the storage of kites, extra kite sticks, and miscellaneous supplies and equipment. Full specifications and sketches are on file at the Central Office of the Weather Bureau. Fig. 2 gives a front view of one of these buildings.

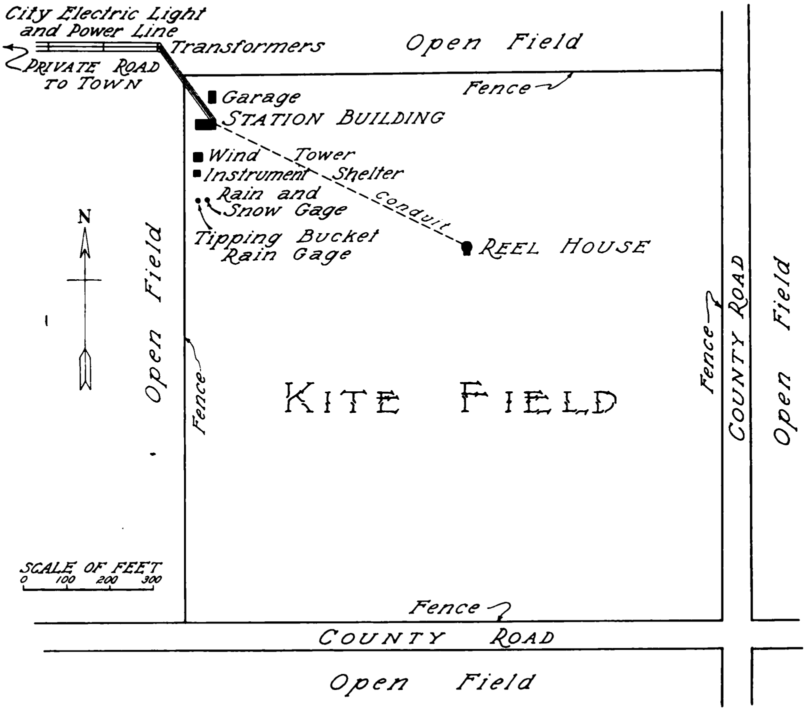

FIGURE 1.—Plot showing the position of buildings and kite field at Ellendale, N. Dak.

II. KITE REEL HOUSE

7. It is necessary to have a small building of special design and construction in order to obtain the best results in kite flying. This building consists essentially of two parts—a turntable, by means of which the doorway may be turned to any desired direction, and a

superstructure sufficiently large to accommodate the kite reel and accessory apparatus. The whole is mounted on a circular concrete wall 20 ins. thick and 30 ins. deep, inclosing a space 10 ft. 8 ins. in diameter. This inner space is excavated to a depth of 2 ft. below the top of the wall, thus providing room for adjusting the electric wiring from time to time and for inspecting the "ground" connections, turntable, etc.

8. The turntable consists of five curved pieces of heavy iron rail, on which the wheels that carry the weight of the building turn, the turning being readily accomplished by means of an endless cable leading from the trucks to a suitable hand apparatus mounted inside the house.

9. The superstructure itself is about 15 ft. in diameter at the floor, tapering to 14 ft. at the eaves. The floor is about 2 ft. 9 ins. above the ground; the eaves, 12 ft., and the peak of the roof, 15 ft. At the front of the building is a doorway about 8 ft. in width and extending from the floor to the eaves. This large doorway is provided because, in addition to the reel and the theodolite which occupy a part of this space, it is necessary for the observers to pass in and out in order to launch or land kites, make observations of clouds, etc.

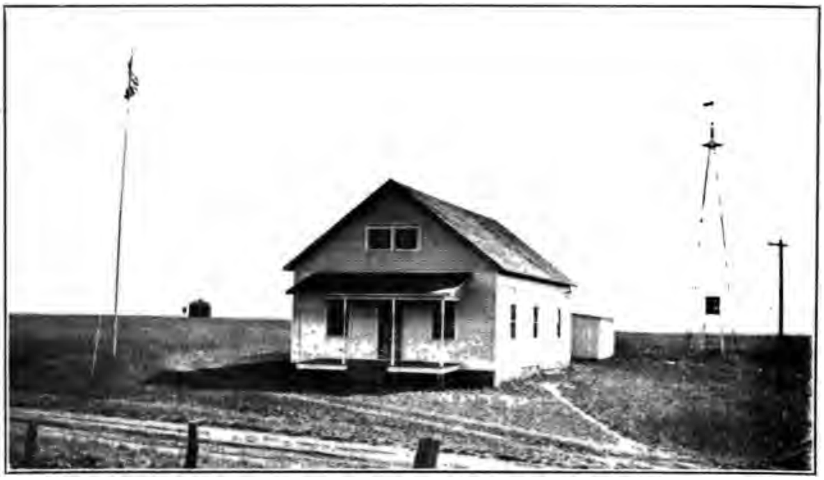

FIGURE 2.—Front view of office and kite storage building at Broken Arrow, Okla.

10. A small window at the rear of the house gives additional light and ventilation, and a trapdoor provides easy access to the space inclosed by the foundation wall. At northern stations it has been found advantageous to have about one-third to one-half of the reel house divided off by a wooden partition, this small room being heated by an oil stove during cold weather to lessen the discomfort of the observers on duty.

11. A wind vane is attached to the top of a vertical shaft extending through the peak of the roof, and at the lower end of this shaft another arrow is fastened with the same orientation, thus making it possible to observe the surface wind direction from inside the reel house.

12. On the left side of the building, as one faces the doorway from the inside, a standard Weather Bureau instrument shelter is installed. This shelter, as is well known, has a double roof to prevent heating of the inside air by the sun's rays. Additional protection is provided in this case by a sloping roof attached to the reel house and projecting about a foot beyond the limits of the instrument shelter. Generally speaking, this extra precaution is unnecessary, since there is usually a good breeze blowing, and therefore plenty of ventilation, while a kite flight is in progress.

13. Complete specifications and drawings for the construction of reel houses are on file at the Central Office of the Weather Bureau. A general view of one of these reel houses is shown in Fig. 3.

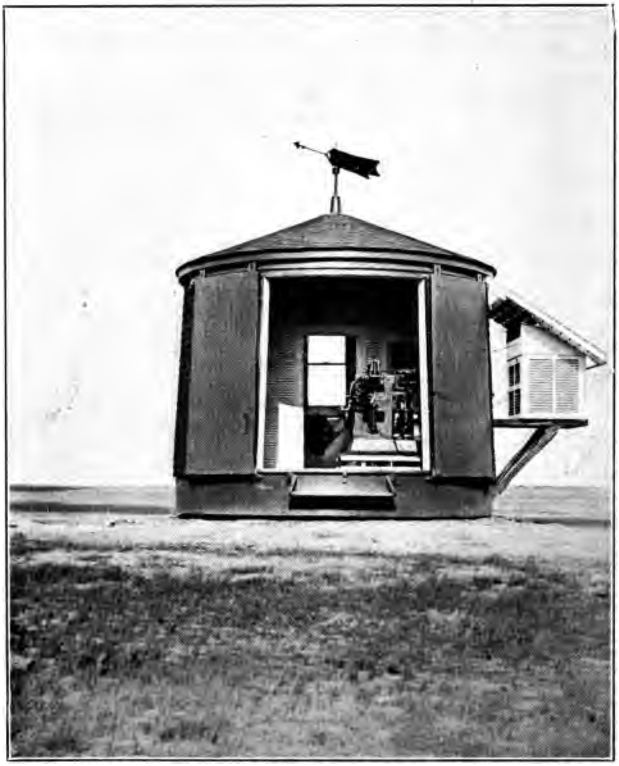

FIGURE 3.—Close view of kite reel house at Ellendale, N. Dak.

III. KITE REEL AND MOTOR

14. *The kite reel*, now in general use at Weather Bureau aerological stations, was originally designed by Prof. C. F. Marvin and later modified by Maj. Wm. R. Blair. Except for the drum, it is made largely of cast iron and its weight is such as to render it stable under any pull that may be exerted by the kites. Two views are shown in Figs. 4 and 5. The most prominent features are the solid base and substantial frame, the drum and the three small wheels which guide the wire from the drum to the kites. One of these

wheels, at the front, is so mounted that it can accommodate itself to the direction which the wire assumes under the influence of the wind's action on the kites. The other two wheels, at the top, are mounted on a distributor carriage which travels back and forth under the action of a cam, shown in the upper right-hand part of Fig. 5.

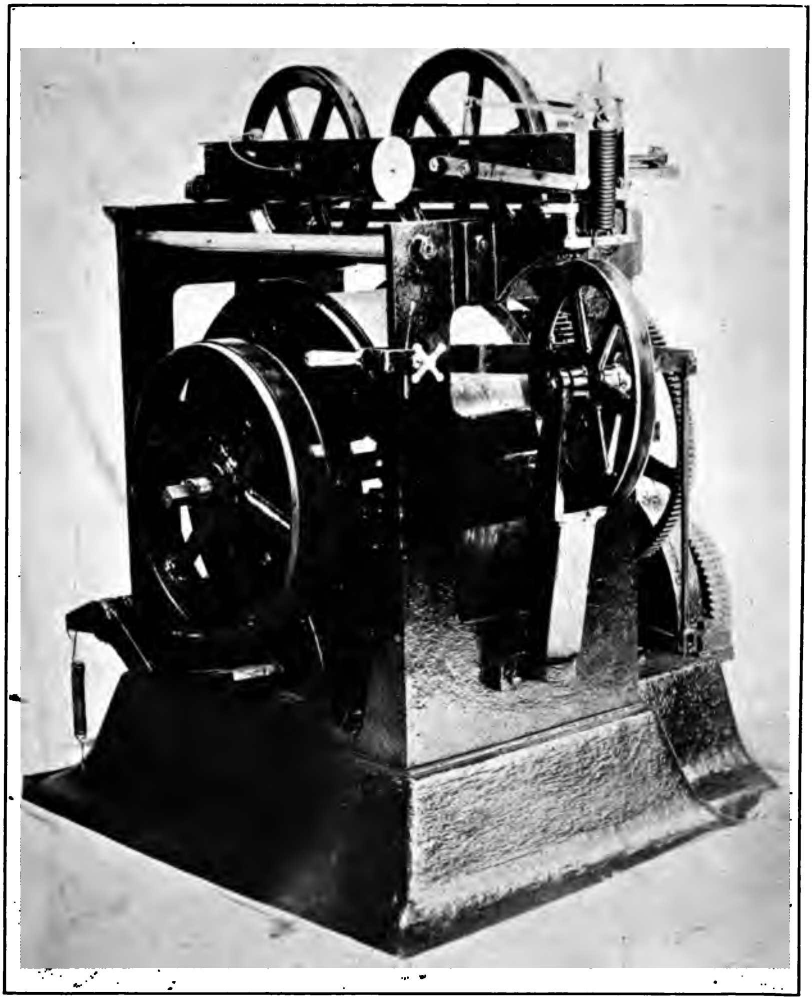

FIGURE 4.—Right front view of kite reel

15. Other details in this figure are the hand brake and the operating gears. In Fig. 4 may be seen the foot brake (auxiliary to the hand brake), a Veeder counter, and a dynamometer for indicating amount of wire out and pull exerted by the kites, respectively. The drum, which is the result of numerous trials with different types, consists of three pieces—the barrel and two spiders. The former is made of cast semi-steel and the latter of cast iron. The spiders

merely center the barrel on the shaft and rotate it, but carry none of the accumulated strain to which the drum is subjected by the piling up of the successive strands of wire. The two brake wheels and two driven gears are mounted on the same shaft with the drum. The latter, shown in Fig. 5, are of different diameter, the larger being for slower speeds. The gears engaging these are always in mesh, and power is applied to either of them by means of a double-throw friction clutch at the rear of the reel within easy reach of the operator.

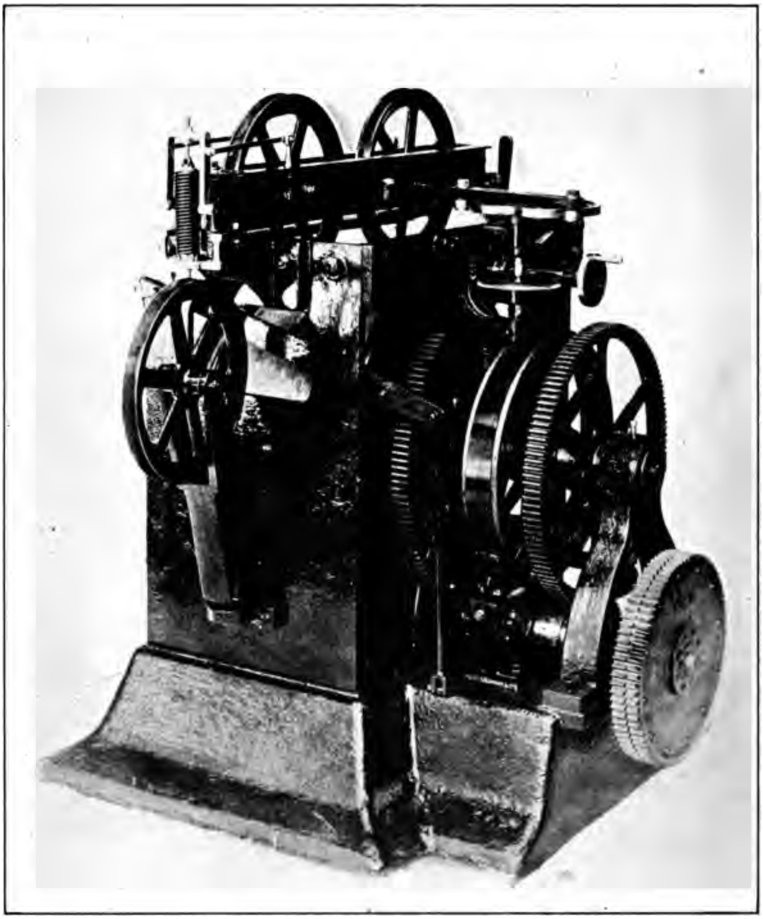

FIGURE 5.—Left front view of kite reel

Complete specifications and drawings for construction of kite reels are on file at the central office of the Weather Bureau.

16. *The kite-reel motor.*—Power is furnished by an electric motor, so designed as to run at any speed between about 400 and 1,800 revolutions per minute, and for any pull up to that equivalent to about 5 horsepower. Such motors can be obtained for either direct or alternating current. Power is transmitted by means of chain and sprockets. One of these motors (for direct current, in this case) is

shown in Fig. 6. Speed is regulated by means of the shaft leading from the motor to a position within easy reach of the operator. As already stated, the speed can be still further regulated by the use of one or the other of the two driven gears shown in Fig. 5.

17. *Protection against lightning.*—Both in and out of the Weather Bureau service the flying of the kites has been attended by danger from lightning to the persons engaged in the work, and it is therefore necessary to use every precaution to avoid possible injuries. In addition, damage to property should be minimized.

18. It is well known that even the wet string used in flying common kites will occasionally permit a considerable discharge to earth during a thunderstorm. But when steel wire is employed to hold a box kite, the metal provides a better conducting path for the lightning. A direct discharge from clouds to earth will quickly melt or vaporize the wire, but the wire will have directed the discharge, the air along the path becoming a good conducting medium by reason of its becoming ionized. There is also occasionally a considerable inductive discharge.

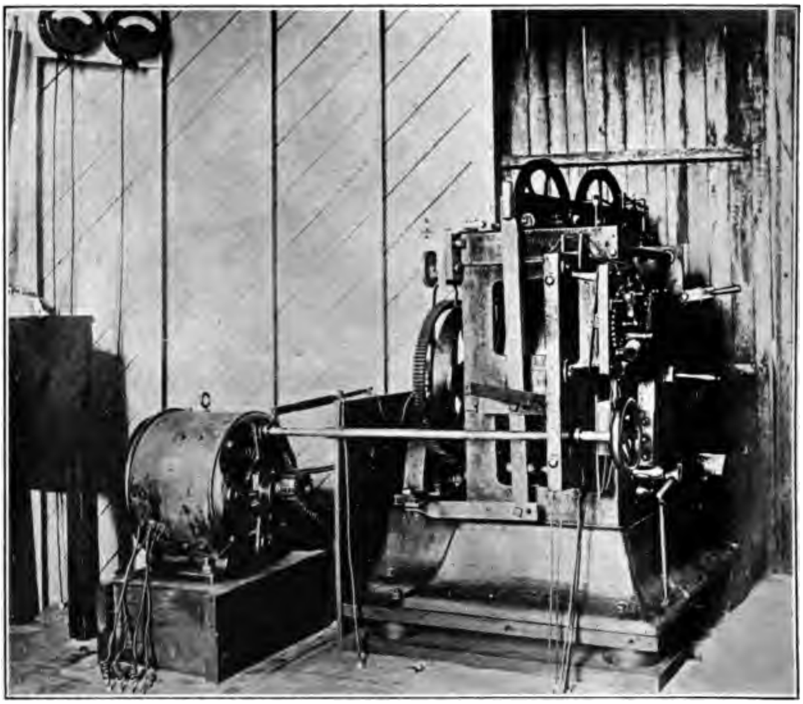

FIGURE 6.—View of rear of kite reel and of variable speed motor

19. From the foregoing, there evidently must be some reliable means for conducting dangerous discharges to earth as well as for completely insulating the reel when it is desired to measure the atmospheric electric potential. This has been accomplished according to the following plan.

20. The kite reel is insulated from the floor by being mounted on blocks of fiber, as indicated in Fig. 6, and the sprocket which is driven by the chain from the motor is composed for the most part of fiber. This insulation makes possible the measurement of electric current on the kite wire. Although such measurements have yielded little of scientific interest, they are useful, especially in summer, as indicators of possible trouble from approaching thunderstorms, when there may be no other evidence. Under such conditions disruptive discharges of considerable intensity sometimes render advisable the shortening of a flight which otherwise might have been continued until too late for completion before the arrival of a thunderstorm.

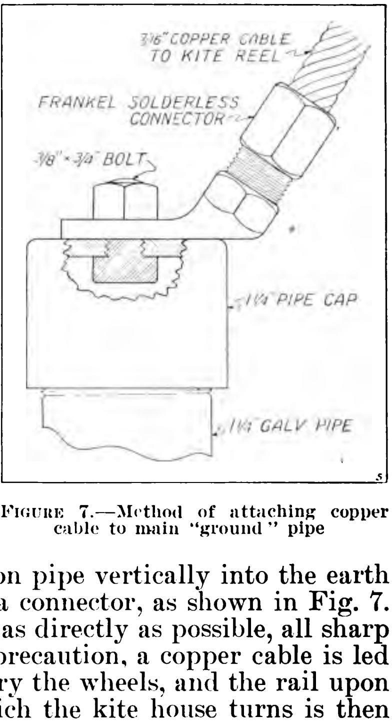

FIGURE 7.—Method of attaching copper cable to main "ground" pipe

21. Accordingly, Weather Bureau stations are furnished with electrostatic voltmeters of the Braun type for this purpose. A long switch, which is opened during these measurements, at other times connects the reel with a $\frac{7}{16}$-in. stranded copper cable to a "ground" formed by driving a 10-ft. length of 1¼-in. galvanized-iron pipe vertically into the earth and fitting the upper end to receive a connector, as shown in Fig. 7. The attachment at the reel is formed as directly as possible, all sharp bends being avoided. As an added precaution, a copper cable is led from the reel to the trucks which carry the wheels, and the rail upon which the kite house turns is then grounded by making four connections through No. 6 copper wire to four 10-ft. lengths of ¾-in. galvanized-iron pipes placed 90° apart just outside the periphery of the structure, as shown in Fig. 8.

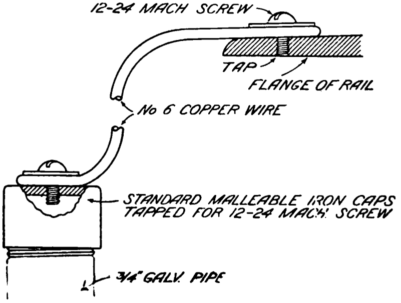

FIGURE 8.—Method of attaching copper wire to "ground" pipes placed at stated intervals around the periphery of reel house

22. The foregoing description and the following instructions should be supplemented by those given in U. S. Department of Agriculture, Farmers' Bulletin No. 1512, which contains general information regarding lightning protection.

23. Attention should, in particular, be given to the grounds to see that they are well made, and it should be known with certainty that the pipes are in contact with soil that is moist throughout the year. Furthermore, the iron-pipe grounds must be periodically inspected to learn to what extent corrosion is occurring, and the pipes replaced

as often as needed. After the connections have been completed to the ground pipes, paint the upper ends of the pipes and the attached fittings with two coats of metallic paint.

24. Following is a list of the material required for protecting one reel house:

12 feet, 7/16-in. copper cable.
2, 7/16-in. solderless connectors.
1, ⅜ by ¾-in. galvanized machine bolt.
1, 1¼-in. galvanized malleable-iron cap.
10 feet, 1¼-in. galvanized standard pipe.
40 feet, ¾-in. galvanized standard pipe.
4, ¾-in. malleable-iron caps.
8, ⅜-in., 12–24, round-head iron machine screws.
8 iron washers for same.
6 feet, No. 6 copper wire.
1 switch for breaking "ground."

25. In addition to the precautionary measures above outlined, it has been found advisable for those engaged in the work to be provided with rubber gloves and boots during thunderstorms. Moreover, the utmost care should be taken in landing secondary kites. The splice wire should be taken off at the reel house and the kite then landed at as great a distance from the wire as possible; otherwise the observer might readily form a short circuit for the lightning from the kite wire to the earth.

26. The end of a heavy 2-inch plank is placed under the reel, which is mounted on insulating blocks just about high enough to hold the plank firmly. This plank then serves as a runway, or platform, from which the kites can be handled without the operator being in contact with the ground; and should the plank become wet it is in contact with the well-grounded kite reel, rather than with the ground direct. This simple device gives the observer additional protection from the atmospheric electricity carried on the wire, and also gives him nearly 3 feet additional height from which to handle a nearly vertical kite wire on a reel-in in squall winds.

27. During severe conditions it is advisable to clamp the brake securely and leave the reel house, with the kites flying, until the passing of the storm.

IV. KITE WIRE

28. In meteorological kite flying, steel music wire, popularly known as "piano" wire, is generally used for the main line; it is far superior to any other material thus far tried for this purpose, because in it are combined the very desirable qualities of great and uniform strength in proportion to weight and bulk, and a smooth surface.

29. This wire is manufactured in a large number of sizes, which are indicated in Table 1. There are also shown the corresponding weights per 1,000-meter lengths and tensile strengths. In consequence of slight variations in diameter the weights and tensile strengths of different lots of wire are likely to vary 5% or more from the values stated, and specimens from the same piece will sometimes vary in strength 2% or more. Also deterioration with use causes a gradual reduction of strength. Accumulated experience indicates that the working stress ordinarily should not exceed two-

thirds of the ultimate tensile strength. It is usually purchased on spools of various amounts and lengths, the smaller sizes, as a rule, being in longer pieces than the larger. For the main line, the longest pieces obtainable should be used in order to avoid the necessity of making numerous splices.

TABLE 1.—*Data of steel music wire used in aerological observations*

Diameter		Weight of 1,000 meters		Ultimate tensile strength	
Millimeters	*Inch*	*Kilograms*	*Pounds*	*Kilograms*	*Pounds*
0. 20	0. 008	0. 29	0. 64	10	22
0. 22	0. 009	0. 33	0. 73	14	31
0. 25	0. 010	0. 40	0. 88	17	37
0. 27	0. 011	0. 49	1. 08	21	46
0. 30	0. 012	0. 59	1. 30	26	57
0. 34	0. 013	0. 69	1. 52	31	68
0. 37	0. 014	0. 84	1. 85	37	82
0. 42	0. 016	1. 05	2. 31	44	97
0. 46	0. 018	1. 32	2. 91	52	115
0. 50	0. 020	1. 63	3. 59	61	134
0. 55	0. 022	1. 95	4. 30	74	163
0. 61	0. 024	2. 25	4. 96	85	187
0. 66	0. 026	2. 60	5. 73	97	214
0. 71	0. 028	3. 08	6. 79	113	249
0. 76	0. 030	3. 56	7. 85	126	278
0. 81	0. 032	4. 00	8. 82	140	309
0. 86	0. 034	4. 52	9. 96	148	326
0. 91	0. 036	5. 00	11. 02	162	357
0. 97	0. 038	5. 71	12. 59	178	392
1. 02	0. 040	6. 37	14. 04	189	417
1. 07	0. 042	6. 94	15. 30	203	448
1. 12	0. 044	7. 46	16. 45	223	492
1. 17	0. 046	8. 33	18. 36	236	520
1. 22	0. 048	9. 09	20. 04	256	564
1. 29	0. 051	10. 00	22. 05	281	620
1. 40	0. 055	11. 48	25. 31	311	686
1. 50	0. 059	13. 51	29. 78	350	772
1. 60	0. 063	15. 63	34. 46	402	886
1. 70	0. 067	17. 54	38. 67	450	992
1. 80	0. 071	20. 00	44. 09	533	1, 175
1. 88	0. 074	22. 22	48. 99	590	1, 301
1. 98	0. 078	24. 39	53. 77	657	1, 448

30. When high flights with a number of kites are desired, larger sizes of wire become necessary, and the usual procedure at aerological stations of the Weather Bureau is to make up the main line of the following sizes: 0.036 in., 500 meters; 0.040 in., 1,500 meters; 0.044 in., 10,000 meters, or 12,000 meters in all. The proportions vary somewhat according to the average wind conditions. In the South, for example, more of the smaller sizes can be used than in the North.

31. When winding the wire on the reel, the end of the wire is attached to the drum or spliced to the outer end of the wire already on the drum, as may be necessary, and the entire coil is then wound on the drum, the reel being run by power or by hand, as preferred.

32. Splicing the wire requires considerable care. As the result of extended experience, it has been found that the best method is to twist the wires evenly about a common axis for a length of 5 or 6 feet, then turn the free ends closely around the main line for a length of about half an inch. In making a splice it is advisable to soften the ends (i. e., where the wire is twisted with the small "twister") and taper them. This reduces the strain at these places when the splice goes over the reel. Splicing is accomplished very readily by

means of simple tools, as shown in Figs. 9 and 10. The two wires to be spliced are held firmly by means of an ordinary machinist's hand vise, having brass jaws to prevent cutting the wire. This hand vise is not shown in the illustrations. The two wires are then placed in the shallow converging slots of the larger "twister," Fig. 9; held in position, but not clamped, by the spring and set screw above the part containing the slots; and finally twisted uniformly, each about a common axis. The free ends are then wound closely around the main wire by means of the smaller "twister," shown in Fig. 10, which scarcely needs explanation.

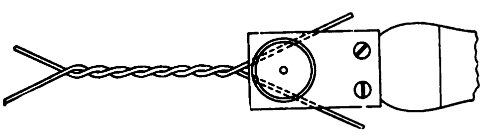

FIGURE 9.—Method of splicing kite wire by means of "large twister"

33. Some difficulty is experienced in making an even splice of two wires of different sizes, and care must be exercised lest the smaller wire be the only one twisted. The process is aided if this smaller wire is held at a greater tension than the larger. It has not been found necessary or desirable to solder the splices, although that practice was followed during the earlier years of kite flying. The end of the wire to which the kite is to be fastened is passed through a swivel and secured to the main line by splicing in the same manner as for ordinary splices, except that a length of about 1½ ft. is sufficient.

34. While the wire is being wound on the drum, machine oil should be poured over it from time to time, in order to prevent it from rusting. This should also be done occasionally after the wire has been used during rainy or snowy weather. Vigilance in this respect is well repaid in reducing the number of breakaways due to defective wire. Moreover, it is well to examine the splices from time to time and to renew them, if the main wire at the ends of the splices shows signs of wear. Such renewal can be effected during kite flights, but a preferable method is to wind the wire from the reel on a small drum, make the splice or splices, and then rewind on the reel. Fig. 11 shows one way of doing this. In winding the wire on the small drum, power is furnished through chain and sprockets by an automobile truck. As soon as all splices have been examined and, if necessary, renewed, the wire is rewound on the drum of the kite reel, power in this case being furnished by the motor in the usual way.

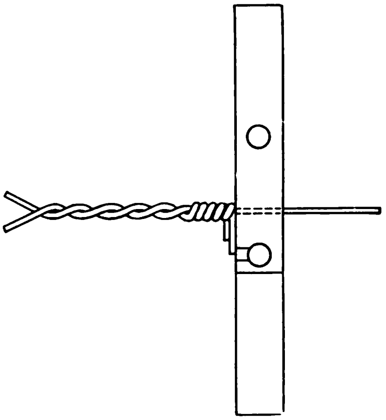

FIGURE 10.—Method of turning end of loose wire around main wire by means of "small twister"

35. During this process it is well to wipe off the old, dirty oil with a piece of waste, then pour new oil on the wire as it is being wound on the drum.

V. KITES AND KITE MAKING

36. In practical kite flying, as exemplified at the aerological stations of the Weather Bureau, the object is to attain as great a height as possible, without incurring serious risk to the kites or line. Obviously, the larger the size and number of kites used, the stronger—and consequently heavier—must the kite line be. Considerations of the effects of wind pressure and ease of handling restrict the diameter of steel wire that it is practicable to use for line to certain narrow limits of tensile strength. Limitations in the dimensions, etc., of the line must, therefore, be met by efficiency in kite performance.

37. Of the qualities that an efficient kite should possess, lightness, stability, and strength are the most important; but lightness must to some extent be sacrificed to realize the ideal practical kite. Of the many types and patterns of kites that have been suggested or tried, the Hargrave cellular kite or some modification of it (in the work of the Weather Bureau, the Marvin-Hargrave) remains the standard. In addition to its good flying qualities, it is perhaps better adapted to the tandem method of flying than is any other type of kite.

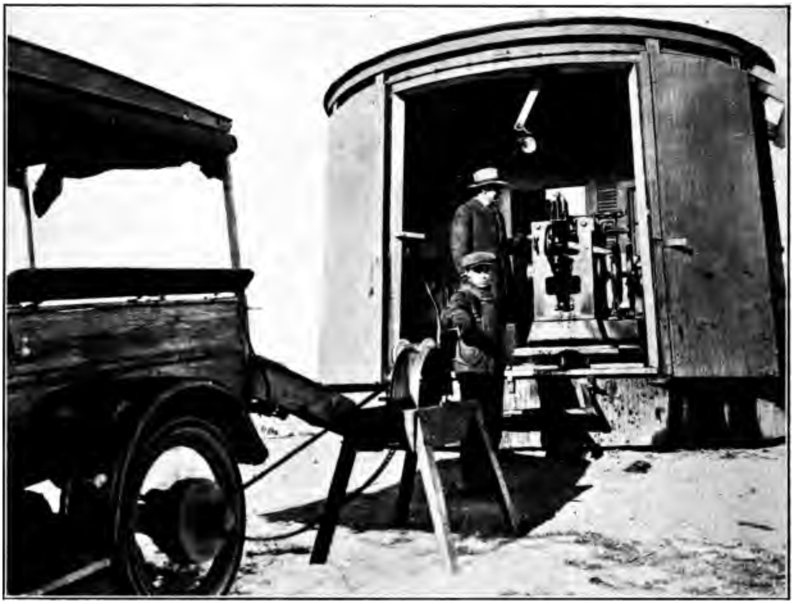

FIGURE 11.—One method of reeling wire from the kite-reel drum to a smaller drum

38. The tandem method of flying and the design of kites and accessories best adapted to it were naturally developed from experience and the knowledge of the atmosphere obtained during early efforts to attain high altitudes by means of kites. Apart from practical reasons, the frequent stratified condition of the atmosphere as regards wind velocity and humidity imposes a limit upon the size of kites

that should be used. It is not often that the wind is so uniform or increases so uniformly with altitude that a high flight can be safely made with one kite large enough to lift the necessary length of line. By distributing the kites along the line, suitably to the prevailing wind and weather conditions, the maximum lifting power of a given surface can be realized, without at any time exposing the whole of this surface to sudden changes in pressure of the wind.

39. Abrupt changes in wind and weather with time or altitude usually affect the lifting surface along only a portion of the line, the total increase of tension of the line from such causes depending largely on the area of lifting surface affected, and the methods for preventing an excessive pull embodied in the construction of the kites. In the Marvin-Hargrave kite, excessive pull is prevented by its method of bridling, described in detail in a later paragraph. This feature of its construction is flexible, permitting a relatively greater margin of safety with increase in size of the kite.

40. The ideal conditions under which a high flight could be successfully made with one kite can not be foreseen with enough certainty to warrant the necessary equipment of suitable line or large kites, even if such equipment were safe or practicable. There is, in addition, the fact that the tension indicated at the lower end of a line from which a single kite is flying is only one factor of the maximum tension on the line. The *maximum tension* occurs at the point on the line where the kite is attached. This is equal to the weight of the vertical projection of the line plus the tension indicated at the reel (less the effect of wind pressure on the line). Under actual conditions, the tension to which the line is subject is a complex of the action of gravity, the pressure of the wind on the line, and the pull of the kite, and departs more from the indications at the reel, the higher and farther away the kite is flying.[1] When the weight of the line is suspended from a number of kites at considerable intervals of distance, the difference between the maximum tension on the line and that indicated at the reel is practically negligible.

41. Under the adopted method of tandem flying, the range or variety in size of kites that it is advisable to build is established by the experience of the kite flier, the mechanical skill of the kite builder, and a knowledge of the tensile strength of the different sections of the line employed. It is unnecessary to build a kite much smaller than one which, under the most severe conditions, will exert a pull nearly equaling the tensile strength of the smallest diameter of line used. In the other extreme, the size of a kite should not go beyond that defined by caution in flying and limit in permissible fragility. One or two intermediate sizes in addition give a complement of kites that serves all purposes of every-day flying, and admits of easy standardization for manufacture.

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[1] Monograph, "The Mechanics and Equilibrium of Kites," by Prof, C. F. Marvin, particularly pp. 64 to 70. (See Monthly Weather Review, April, 1897.) This monograph was submitted in competition for, and was awarded, the Chanute prize offered in 1896 by the Boston Aeronautical Society "for the best monograph on the kite, giving a full theory of its mechanics and stability, with quantitative computations appended." It was written at a time when the mechanics of the cellular kite—the projenitor of the heavier-than-air machine—was being closely studied. The student of the equilibrium of kites is referred to this monograph in its entirety for a full mathematical treatment of the subject.

42. The *Marvin-Hargrave kites* now used are essentially of the same type and construction as those devised by Professor Marvin[2] and used at 17 stations during the Weather Bureau kite-flying program of 1898. The only important modifications that have been introduced since that date are in the dimensions and in the adoption of the elastic bridle, experience having shown that a smaller and stronger size of kite is required for high winds, while for light winds a greater spread of lifting surface is necessary.

43. Three sizes of kites are illustrated in Figure 12. They are classed as "high-wind" kites (Nos. 1 to 9, inclusive); "moderate-wind" or "standard" kites (Nos. 10 to 29, inclusive); and "light-wind" kites (Nos. 40 to 49, inclusive). A fourth size (Nos. 30 to 39, inclusive), slightly larger than the standard but smaller than the "light-wind" kites, and a fifth size (Nos. 50 to 59, inclusive), which is the largest of all, are also used. The details of construction for the different sizes are precisely the same (except for sizes 50 to 59), the only differences being in the dimensions and proportions. As will be understood from the description and detail drawings which follow, this form of construction has certain advantages and disadvantages. One of the chief disadvantages is its frailty. Collision with the ground or other object almost invariably causes a bad smash of the kite; likewise, when the sails become water-logged the shrinkage of the cloth combined with the pressure of the wind is frequently powerful enough to crush the framework of the kite. On the other hand, broken sticks are easily and quickly replaced and the kite itself is conveniently collapsed for shipment.

44. The kite consists of two cells joined together by longitudinal strips or sticks of straight-grained spruce. The front cell has a middle plane, and in this respect it differs from the original Hargrave pattern. The details which follow refer to what is known as the "standard" kite. This size, modeled after the pattern used in 1898, has been found to be suitable for a wide range of wind velocity and weather conditions. When properly built it will fly well in winds of from 12 to 30 miles an hour (5 to 13 m. p. s.) near the ground, and 70 miles an hour (31 m. p. s.) when 2 to 3 miles (3 to 5 km.) high. Its extreme dimensions are as follows:

Length or distance fore and aft	6′ 8½″
Width or distance between the outside vertical surfaces	6′ 4½″
Height or distance from top to bottom of cell	2′ 8½″

45. The area of sustaining or lifting surface is 63.8 sq. ft. (5.9 sq. meters), and of steering or neutral surface 21.7 sq. ft. (2 sq. meters). The kite weighs about 9 lbs. (4.1 kg.).

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[2] Concerning the history of the meteorological kites now used in the United States, it may be of interest to note that in the early days of kite flying at Blue Hill Observatory, Massachusetts, H. Helm Clayton made many improvements on the Hargrave box kite of 1895. The most important modification was the use of longitudinal sticks connecting the two cells at their outer corners, thereby greatly increasing the strength and stability of this kite. Professor Marvin added the excellent folding feature, which not only makes it easy to ship kites, but also allows ready reassemblage with unimpaired strength.

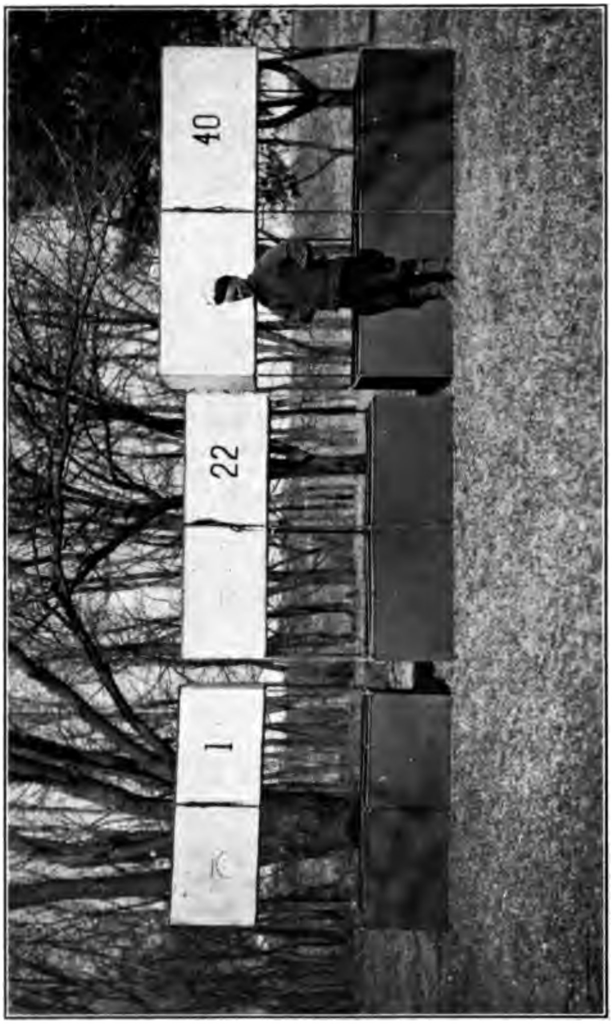

FIGURE 12.—Various sizes of kites used

46. The *material required* in the construction of the *standard-size kite* includes:

(*a*) Forty-three sticks of the following dimensions:

Number of sticks		
1,	⅝" by ½" by 7' 6".	Center bridle; square edges.
1,	⅝" by ½" by 6' 10".	Top center; square edges.
4,	⅝" by 5/16" by 6' 10".	Longitudinal or corners; square edges.
8,	⅝" by 5/16" by 6' 6¼".	Lateral or sewed; rounded edges.
12,	⅝" by 5/16" by 2' 7½".	Vertical, corner struts; rounded edges.
8,	⅜" by 5/16" by 2' 7½".	Intermediate struts; rounded edges.
6,	⅜" by 5/16" by 3' 2".	Lateral centers; rounded edges.
3,	⅝" by 5/16" by 2'.	Middle sail longitudinal sticks; rounded edges.

The sticks are made of straight-grained spruce. All horizontal sticks should have their edges rounded, so that the end resistance of the kites to the wind will be as small as possible.

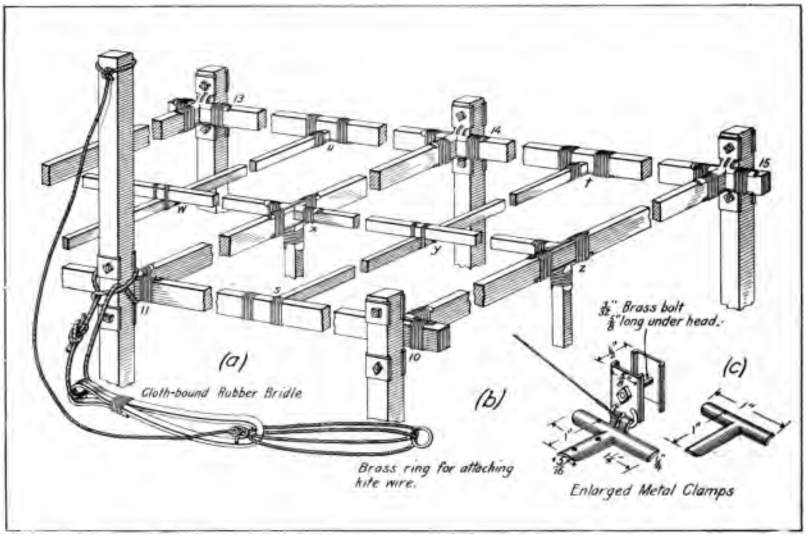

FIGURE 13.—Showing method of fastening corners of kite sticks and bridle to kite

(*b*) Fourteen yards of Lonsdale cambric[3] 26 in. wide are used for the sails; some coarse waxed linen thread for lashing angles to sticks; 192 ft. of piano wire, 0.024 in. diameter, for guys.

(*c*) Forty-eight metal angles of the pattern shown in detail at (*b*) in Figure 13 form the principal joints, 1 to 24, Figure 14; 34 metal angles of another pattern, shown at (*c*) in Figure 13, are used for all intermediate joints, excepting at *b'*, *d'*, *n*, *p*, *y*, and *w*, which are lashed to the sticks with waxed 4-ply gilling thread. The isometric detail, Figure 13(a), shows how these joints are fastened. These metal angles are made of brass especially for this purpose.

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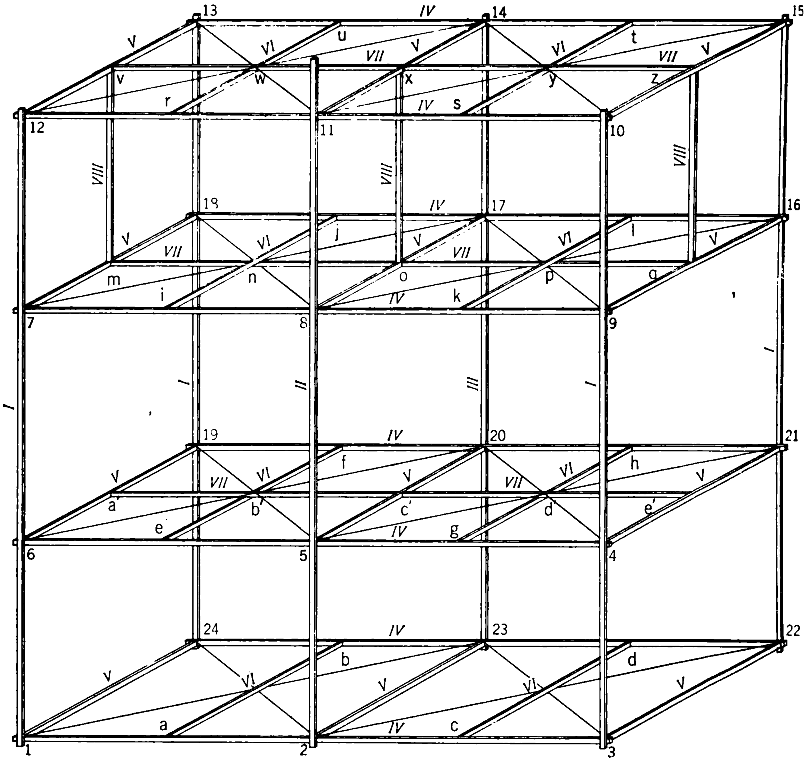
[3] The rear cell and sometimes both cells are covered with a black fabric known to the trade as "mercerized" silk or French percaline, "batiste," etc. It has the property of shedding water to a much greater extent than cambric. For that reason kites covered with it are preferred during fog. Most kites are made with a white front cell and a black rear cell, the contrasting colors being very desirable for visibility.

47. Figure 15 is an elevation of the front or bridle face of the kite—i. e., the lower surface when flying. The opposite face—i. e., the upper or rear surface of the kite—is the same except as to the size and length of the bridle stick.

48. Figure 16 shows a sectional elevation showing the central or bridle truss, and an elevation of one of the two side trusses. The fine diagonal lines in Figures 14, 15, and 16 show the system of wire bracing necessary to preserve the form and rigidity of the framework. This bracing is all done with piano wire (0.024″) secured to the metal angles, as shown at (*b*) in Figure 13 for the vertical cross bracing. In the horizontal and long vertical bracing the wire is looped over the small bolt head in the metal angles before the bolt is tightened up. All metal angles are lashed to the sticks with well-waxed linen thread.



DIMENSIONS OF STICKS DESIGNATED BY ROMAN NUMERALS

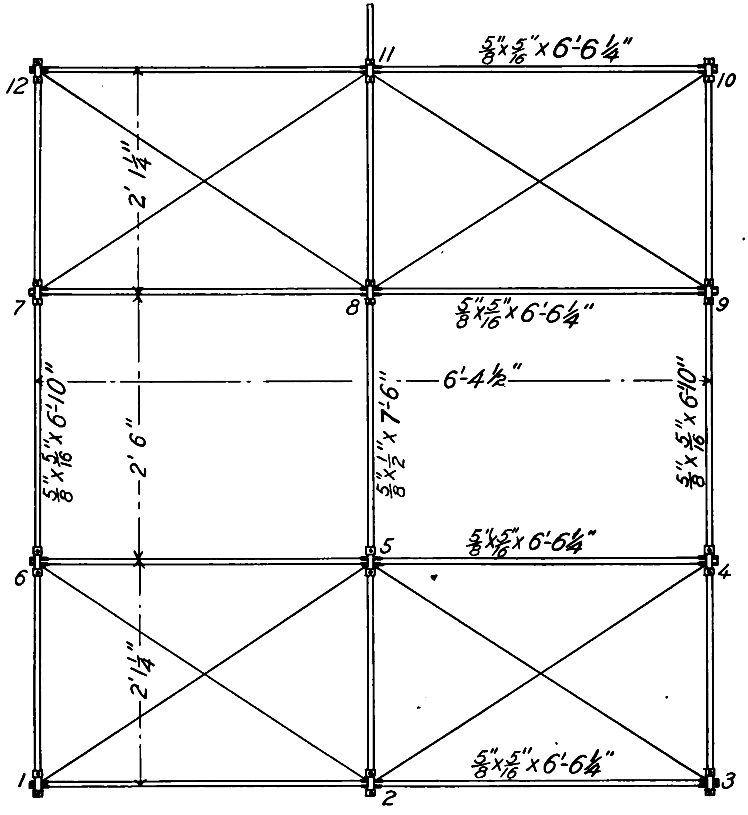
I – 5/8″ X 5/16″ X 6′–10″ II – 5/8″ X 1/2″ X 7′–6″ III – 5/8″ X 1/2″ X 6′–10″ IV – 5/8″ X 5/16″ X 6′–6¼″

V – 5/8″ X 5/16″ X 2′–7½″ VI – 3/8″ X 5/16″ X 2′–7½″ VII – 3/8″ X 5/16″ X 3′–2″ VIII – 5/8″ X 5/16″ X 2′–0″

FIGURE 14.—Iscmetric view of kite frame (standard)

49. After the frame is put together and securely braced, care being taken that all angles are true and square, the kite is ready for

the sails. These are made from white Lonsdale cambric, 2 ft. 2 in. wide and 18 ft. 4 in. long, and are double hemmed one-half inch on each edge and each end. A soft cord should be passed through this hem to lessen the danger of tearing. The sails are stretched around the kite frame and lashed to the horizontal and vertical sticks with waxed gilling thread.



Kite Sticks, Clamps &c.

1-5/8"x1/2"x7'-6"	square edges
1-5/8"x1/2"x6'-10"	" "
4-5/8"x5/16"x6'-10"	" "
8-5/8"x5/16"x6'-6 1/4"	rounded edges
12-5/8"x5/16"x2'-7 1/2"	" "
8-3/8"x5/16"x2'-7 1/2"	" "
6-3/8"x5/16"x3'-2"	" "

3-5/8"x5/16"x2' rounded edges
48 Metal clamps-Fig. 13 (b)
34 " " " " (c)
192 ft. 0.024" piano wire
14 yds. Lonsdale Cambric or mercerized silk 26" wide

FIGURE 15.—Front view of kite showing brace wires (standard)

50. A middle sail is placed in the center of the top section, extending from m v to q z (see fig. 14). This sail should be exactly 2 ft. wide and 6 ft. 4½ in. long after being hemmed, as described for the main sail, and should be lashed to the sticks in a similar manner.

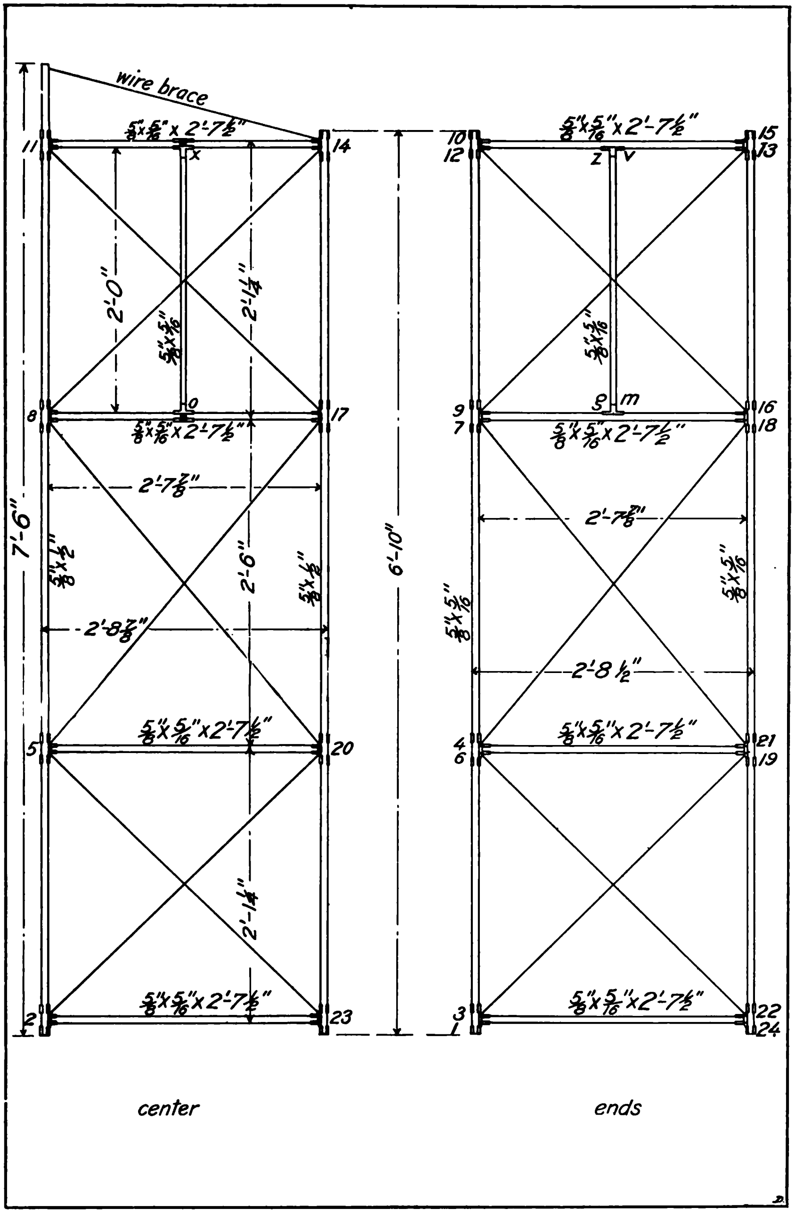


Figure 16.—Side view of kite showing brace wires (standard)

51. In the *high-wind kite* (Nos. 1 to 9, inclusive) the proportions and dimensions of the "standard" size are preserved, except that

the width is made 11 in. less, thus reducing the width of the lifting surfaces and relatively increasing the area of neutral surface. It has a lifting surface of 54.6 sq. ft. (5.1 sq. meters). This kite has been successfully flown in an 80-mile per hour (36 m. p. s.) wind at an altitude of 1 mile (1,600 meters) above the ground. The dimensions of the "high-wind" kite are the same as those for the "standard" (See Par. 46), except in width, viz:

Eight sticks, ⅝" by 5/16" by 5' 7¼". Lateral or sewed (rounded edges).
Six sticks, ⅜" by 5/16" by 2' 8½". Lateral centers. (rounded edges).

52. In the *light-wind kite* (Nos. 40 to 49, inclusive) the change in proportions from the "standard" is the reverse of that of the "high-wind" kite—i. e., the width is increased in proportion to the length fore and aft. The dimensions are increased over all, giving this kite a lifting surface of 93 sq. ft. (8.6 sq. meters) and a weight of 11½ lbs. (5.2 kg.). It will fly in a slightly lighter wind than the "standard," but its chief advantage is characteristic of all large kites—it will lift more line after it has ascended into a current stronger than necessary to lift itself. Its ability to fly in a lighter wind is due to the fact that it is lighter for the same lifting surface than the other kites. The frailty of this kite is partly compensated for by the fact that it is used only when surface winds are light to moderate, and the chances of the kite's striking the ground consequently small. It is not used when wind velocities aloft exceeding 30 miles per hour (13 m. p. s.) are expected; for, while it has been found to possess fairly good flying qualities in a 50-mile-per-hour (22 m. p. s.) wind at an altitude of 2 miles (3,200 meters), smaller kites can be more easily handled and more advantageously used in the stronger winds. The dimensions of the "light-wind" kites are as follows:

Number of sticks
1, ⅝" by ½" by 8' 2". Center bridle; square edges.
1, ⅝" by ½" by 7' 5⅝". Top center; square edges.
4, ⅝" by ⅜" by 7' 5⅝". Longitudinal or corner; square edges.
8, ⅝" by 5/16" by 8' 0". Lateral or sewed; rounded edges.
12, ⅝" by 5/16" by 3' ¼". Vertical corner struts; rounded edges.
8, ⅜" by 5/16" by 3' ¼". Intermediate struts; rounded edges.
6, ⅜" by 5/16" by 3' 11⅜". Lateral centers; rounded edges.
3, ⅝" by 5/16" by 2' 4". Middle sail longitudinal; rounded edges.

53. The dimensions of the intermediate size kite (Nos. 30 to 39, inclusive) are the same as those for the "standard" except in width, viz:

8 sticks, ⅝" by 5/16" by 7' ¼". Lateral or sewed (rounded edges).
6 sticks, ⅜" by 5/16" by 3' 5¾". Lateral centers (rounded edges).

54. The dimensions of the largest size kite (Nos. 50 to 59, inclusive) are as follows:

Number of sticks
1, ⅝" by ½" by 9' 3¾". Center bridle stick; square edges.
1, ⅝" by ½" by 8' 7". Top center; square edges.
4, ⅝" by ⅜" by 8' 7". Longitudinal or corners; square edges.
8, ⅝" by 5/16" by 8' 11". Lateral or sewed; rounded edges.
20, ⅝" by 5/16" by 3' 4". Vertical struts; rounded edges.
8, ⅜" by 5/16" by 4' 5". Intermediate longitudinals; rounded edges.
3, ⅝" by 5/16" by 2' 7". Lateral centers; rounded edges.
6, ⅝" by 5/16" by 2' 10". Middle sail longitudinal; rounded edges.

The 50 to 59, inclusive, size kite has a slightly different system of wire bracing and a few extra sticks. This design is shown in Figure 17. The additional bracing adds but little to the total weight while the strength is increased considerably. It flies well not only in winds which are too light for the other size kites but also in winds of considerable force.

55. With a given pattern of kite, any increase in size, without a more than corresponding increase in weight, will be at the sacrifice of rigidity of the framework. In the sizes of kites described and other sizes and shapes that have been experimented with in the past, there is only a small range in the minimum wind velocities in which they will rise from the ground. The excess of wind velocity above that necessary to fly the unburdened kite will be available to lift a weight roughly in proportion to the lifting surface.

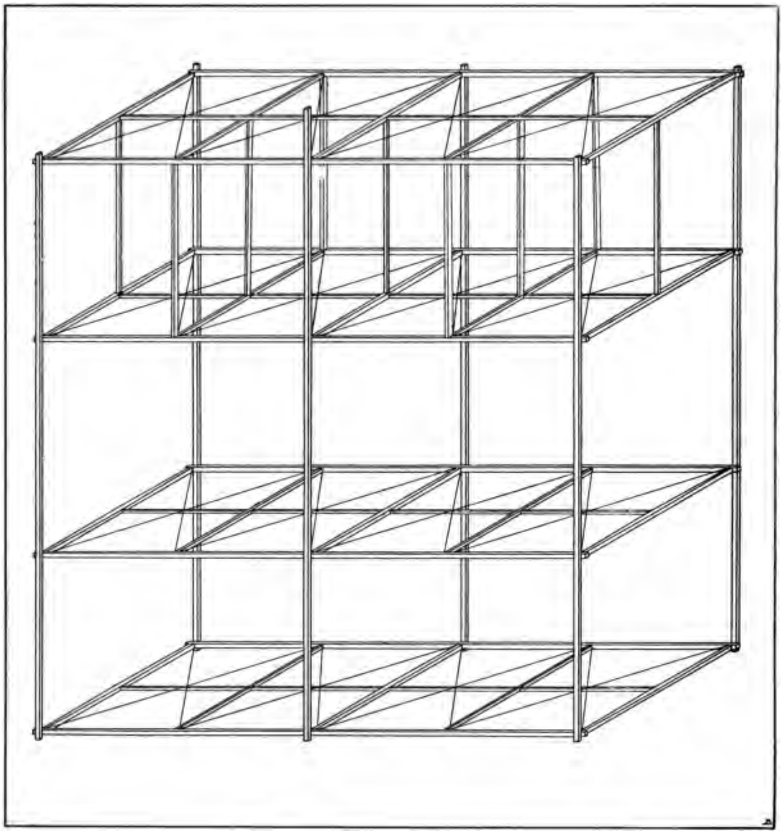


FIGURE 17.—Isometric view of kite frame (size 50 to 59, inclusive)

56. The lifting capacity of a Hargrave kite is partly a function of its shape. For a given area of horizontal sail surface, the lifting capacity can be increased by making it wider relative to its length, since, in all kites the pressure of the wind is greatest near the front

edge of the sails.[1] By increasing the length and depth relative to the width, the lifting capacity is lessened, but the stability of the kite improved. However, not much latitude is permitted the kite builder in either direction, as on the one hand a kite proportionally too wide will fly badly in any considerable wind, while a kite too long and deep will not have lifting power enough, in relation to the pull it is capable of, to justify its use.

57. A certain sturdiness of framework is necessary in all kites, not only to minimize breakage from inevitable collisions with the ground, but also to maintain good flying properties in strong wind. The wire ties in the Marvin-Hargrave kite serve to hold the framework symmetrical as a whole, and add little to the weight. A kite so braced will not collapse in any wind in which it is advisable to fly. An exception occurs when the sails become wet, but under such circumstances frailty is sometimes an advantage, by preventing a possible breakage of the line. However, unless the sticks are given an adequate thickness, distortion or deformation of the frame and sail surfaces, and consequent erratic action of the kite, will result during strong winds.

58. The stability of any kite is observed to increase with height above the ground, especially the first few hundred meters. For a considerable distance above the ground, the ability of a kite to withstand strong wind increases at a rate greater than can be accounted for by the diminishing density of the air. There seems little doubt that this can be explained entirely by turbulence, gustiness, eddies and convectional currents, the effects of which on the kite are strongest near the ground.

VI. KITE METEOROGRAPH

59. The Marvin meteorograph used in kite observations is an ingenious combination of well-known devices used in recording pressure, temperature, humidity, and wind velocity. (Fig. 18.) The essentials of the instrument are a light, rigid, horizontal tube inclosing the anemometer, temperature element and hygrometer hairs. The pressure element is mounted on the frame beneath the tube. The recording pen arms supported from above oscillate through a vertical plane.

60. The instrument is constructed chiefly of aluminum and weighs 750 grams (1.6 lbs.), exclusive of the aluminum case, which weighs 250 grams (0.6 lb.), into which the instrument fits. No part, except the inside of the screening tube and the anemometer head, is exposed to the weather. The screening tube is insulated from the case by two strips of bakelite.

61. During a flight the meteorograph is tied inside the kite in such position that the wind passes freely through the tube containing the temperature element and hygrograph hairs. Thus a very good exposure is obtained, the ventilation being ample, since the wind is always strong enough to support the kite, and the effects of insolation are further minimized or eliminated by the shading of the instrument by the kite.

62. *Clock.*—The clock is of special design with full jeweled anchor escapement and rotates the drum once in 6½ hours. The recording

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[1] See footnote 1, p. 14.

cylinder, inclosing the clock, is rigidly set within the frame of the instrument, but is easily removed in order to renew the record sheet by loosening the thumb nuts on each end of the axis, the thumb nut to the left serving also for winding the clock.

63. *Pressure element.*—The pressure element is of the sylphon type and the range of the pen is such that a movement of 50 mm. corresponds to a height of 5 km. (approximately). Heights to 7 km. can be recorded with this range of the pen.

64. *Temperature element.*—The temperature element is a curved bimetallic strip of duplex metal prepared by permanently welding throughout their entire length two metals having widely different coefficients of expansion. The combination of metals used, Invar steel and special brass, gives the greatest amount of deflection per degree of temperature change that can be obtained with reliability and sensitivity.

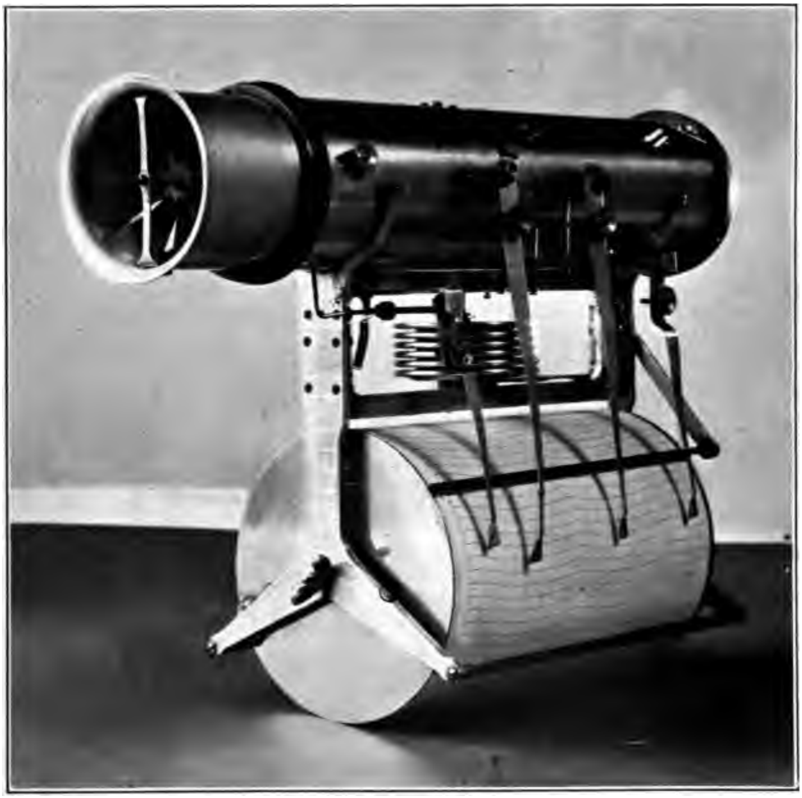


FIGURE 18.—Marvin kite meteorograph

65. *Humidity element.*—This consists of a number of human hairs mounted longitudinally in the horizontal screening tube. The hairs are mounted separately instead of in a bundle, as this makes the element respond more quickly to changes in humidity. The hairs are connected as directly as possible with the recording pen, thus reducing to a minimum the possibility of lost motion or friction in

the bearings. Two sets of hairs are used which is equivalent to doubling their length, hence the movement of the pen arm is twice that of a single length.

66. Before mounting, all of the hairs are subjected to the same conditions of temperature and humidity as well as the same tension and are then fastened firmly with shellac. It has been found that an element in which the hairs are thus mounted responds very quickly to changes in humidity, whereas, when the hairs are arranged in a bundle they require an appreciably longer time to change from dry to wet conditions and especially from wet to dry.

67. *Wind element.*—This consists of a small fan set in the wind-facing end of the tube. The fan is geared to a cam, which in turn actuates the pen arm, thus recording directly the wind velocity in miles per hour. The pitch of the fan blades can be easily changed to adjust the scale value.

68. *Record sheet.*—Form No. 1101 (Fig. 19) is used for this purpose. Under extreme conditions it should be possible for the pens to record outside their ordinary limits. Thus at a height of 6 or 7 km. the pressure pen should record in the humidity space and the temperature pen in the pressure space. Likewise, humidities above 60 to 70 per cent should be recorded in the pressure space. There should be no interference of the pens at such times, since the humidity pen records to the right of the pressure pen at any particular ordinate.

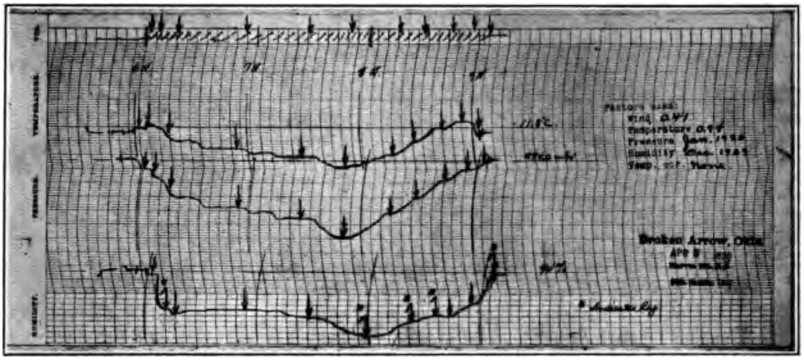


FIGURE 19.—Record of kite flight made at Broken Arrow, Okla., on April 3, 1930

VII. CALIBRATION OF METEOROGRAPHS

69. A meteorograph in regular use should be recalibrated at least every three months. However, if it receives a severe jar it should be tested oftener. Extra meteorographs held at stations should be calibrated at least every six months.

70. After placing a record sheet on the cylinder the latter is placed in the frame and tightened by means of the knurled nut. However, this should never be tightened with pliers but always with the fingers. For convenience in testing these instruments a stand is made of two parallel strips of wood with ridges provided for the lower part of the frame. This stand holds the instrument in the proper position and allows the cylinder to move freely.

71. The pens are filled with the special ink provided and the adjusting nuts on the pen arms screwed down until the pens press lightly against the paper. The pressure of the pens is very important and should be such that they will just leave the sheet when the instrument is held in an inverted position.

72. The pens are made to ink properly by drawing a stiff piece of paper between the points. A knife or thick object should never be used for this purpose.

73. Before calibrating a meteorograph it should be carefully examined for defects. There must be no lost motion nor binding in the linkage system of any of the elements, i. e., the pens must return to their original position when moved. They must record freely and properly throughout their range. Care must be taken to see that the pens bear against the record sheet with exactly the same tension throughout their entire range. The meteorograph should never be lifted by grasping the ventilating tube but should always be held by the frame work. In case the instrument does not function satisfactorily in all respects the trouble should be remedied. This must always be done with the greatest of care and preferably by an experienced instrument maker. The hairs of the humidity element must never be touched with the bare fingers. Any particle of oil or grease renders them useless.

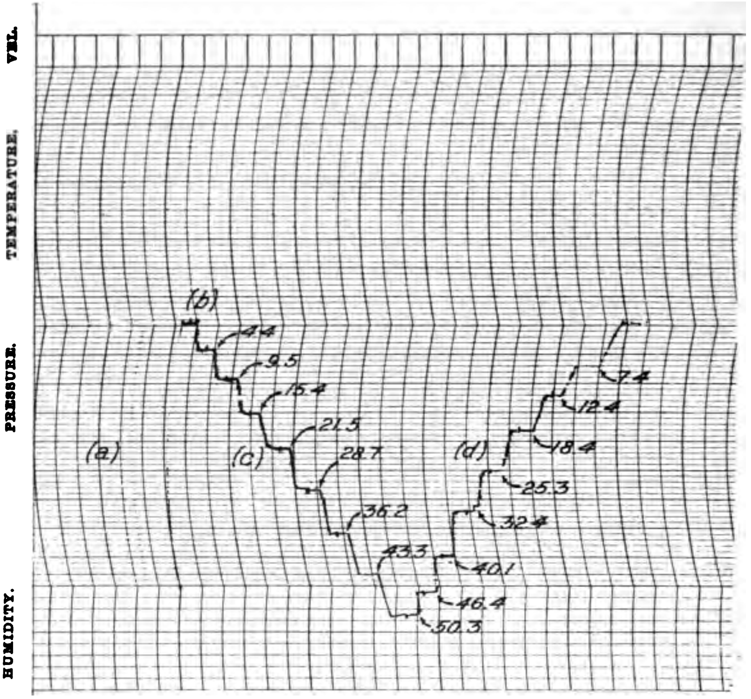


FIGURE 20.—Marvin kite meteorograph pressure calibration trace

74. *Pressure calibration.*—The calibration apparatus consists of a bell jar, vacuum pump, manometer (U-shaped is used by the Weather Bureau) and attached thermometer.

75. The meteorograph is placed on a wooden stand inside the bell jar. The air is then drawn out until the pressure pen, having started from the top of the pressure space, reaches the second or third line of the humidity space (one humidity ordinate is equal to two pressure ordinates) as shown at (a) in Figure 20. The manometer, at this low point, should indicate a pressure equivalent to a height of 5 km. above sea level (approximately). For example, if the sea-level pressure is 1,013 mb., then the pressure at the low point, referred to above, should be between 490 and 510 mb. If this is not found to be the case, the air should be allowed to reenter the jar slowly, i. e., in not less than one minute (never suddenly), the range of the pen adjusted, and the same procedure followed until the proper range is secured.

76. The pen must return to its starting place, i. e., to at least within one or two tenths of an ordinate (see (b) in Figure 20). The range of the pressure pen can be increased by moving the link connecting the pen arm inward, i. e., closer to the center of rotation. After the proper range has been obtained the pressure is reduced at intervals as shown at (c) in Figure 20. The "steps" are increased gradually, i. e., the number of ordinates between them, as the lower pressures are attained. The air is then allowed to return to the jar as indicated at (d). The "steps" on the return (air-in) should be made approximately half way between those of the exhaust (air-out). This provides better data for plotting when obtaining the mean curve.

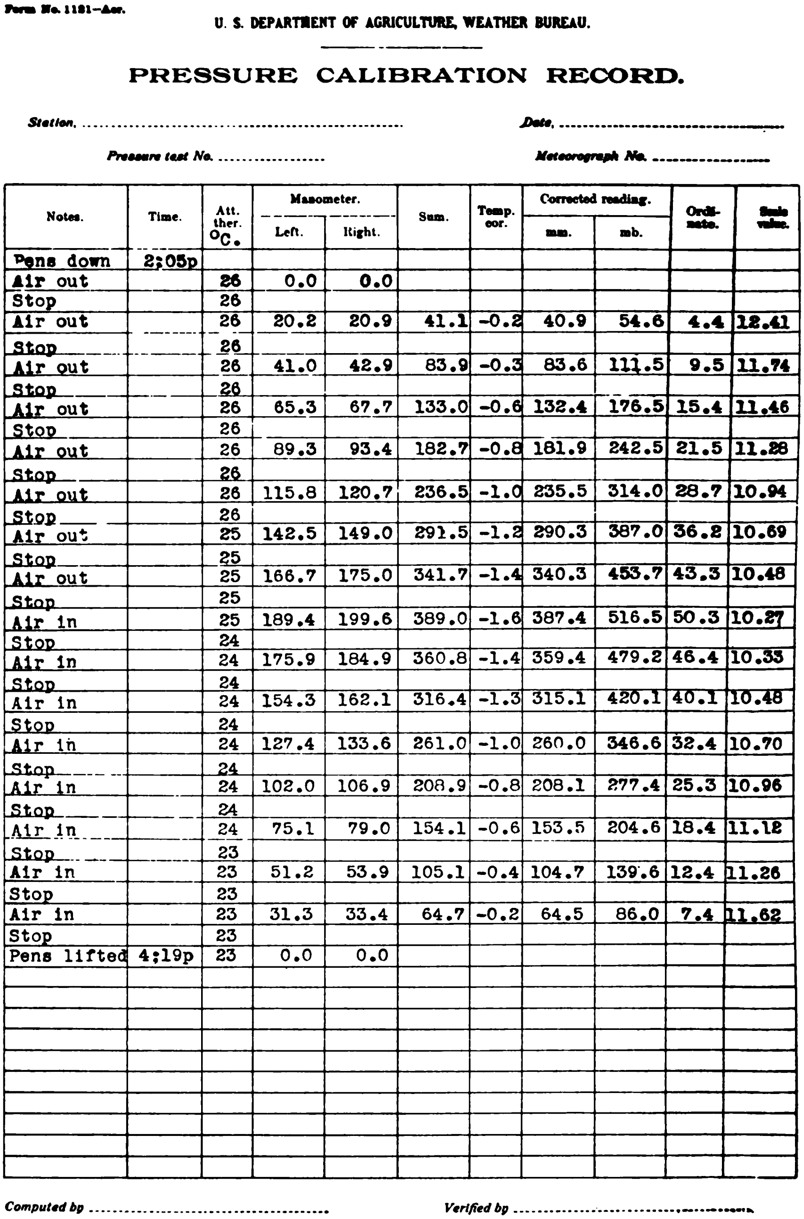
77. In order to simulate actual flight conditions better, about one hour should be taken to reduce the pressure, as at (c), to the lowest point and an equal time to allow the air to return, as at (d), Figure 20.

78. The instrument must be jarred a short time (about one-half minute) before reading the manometer at each "step" so that the pen will properly adjust itself. In actual flight the instrument receives sufficient vibration so that the pens are constantly adjusted under those conditions.

79. On Form 1121 are entered the manometer readings and other data as shown in Figure 21. The manometer should be read at the end of each step, i. e., just previous to letting the air in or out of the jar. These readings will then correspond with the points indicated by arrows. (See fig. 20.) The accumulated ordinates are entered on Form 1121. (See fig. 21.) The attached thermometer readings should be entered; also the temperature corrections which are obtained from the Smithsonian Meteorological Tables. Since millibars are the pressure units used in aerological observations, it is necessary to convert the manometer readings into these units. The scale values which are entered in the last column of Form 1121 are obtained by dividing the pressure difference in mb. by the corresponding ordinate difference. For example, the first scale value entered, viz, 12.41 is the quotient of 54.6÷4.4. The scale value for the maximum ordinate is obtained for both the "exhaust" and "intake" and may differ slightly.

80. When calibrating an instrument which has not recently been in use the above procedure should be carried out at least three times,

allowing at least 24 hours to elapse between each cycle. For instruments in regular use it is usually necessary to make only two cycles, provided good agreement is found between them.



Form No. 1181—Aer.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

PRESSURE CALIBRATION RECORD.

Station, ... *Date*, ...

Pressure test No. .... *Meteorograph No.* ....

Notes.	Time.	Att. ther. °C.	Manometer.		Sum.	Temp. cor.	Corrected reading.		Ordinate.	Scale value.
			Left.	Right.			mm.	mb.		
Pens down	2;05p									
Air out		26	0.0	0.0						
Stop		26								
Air out		26	20.2	20.9	41.1	-0.2	40.9	54.6	4.4	12.41
Stop		26								
Air out		26	41.0	42.9	83.9	-0.3	83.6	111.5	9.5	11.74
Stop		26								
Air out		26	65.3	67.7	133.0	-0.6	132.4	176.5	15.4	11.46
Stop		26								
Air out		26	89.3	93.4	182.7	-0.8	181.9	242.5	21.5	11.28
Stop		26								
Air out		26	115.8	120.7	236.5	-1.0	235.5	314.0	28.7	10.94
Stop		26								
Air out		25	142.5	149.0	291.5	-1.2	290.3	387.0	36.2	10.69
Stop		25								
Air out		25	166.7	175.0	341.7	-1.4	340.3	453.7	43.3	10.48
Stop		25								
Air in		25	189.4	199.6	389.0	-1.6	387.4	516.5	50.3	10.27
Stop		24								
Air in		24	175.9	184.9	360.8	-1.4	359.4	479.2	46.4	10.33
Stop		24								
Air in		24	154.3	162.1	316.4	-1.3	315.1	420.1	40.1	10.48
Stop		24								
Air in		24	127.4	133.6	261.0	-1.0	260.0	346.6	32.4	10.70
Stop		24								
Air in		24	102.0	106.9	208.9	-0.8	208.1	277.4	25.3	10.96
Stop		24								
Air in		24	75.1	79.0	154.1	-0.6	153.5	204.6	18.4	11.12
Stop		23								
Air in		23	51.2	53.9	105.1	-0.4	104.7	139.6	12.4	11.26
Stop		23								
Air in		23	31.3	33.4	64.7	-0.2	64.5	86.0	7.4	11.62
Stop		23								
Pens lifted	4;19p	23	0.0	0.0						

Computed by .... *Verified by* ....

FIGURE 21.—Marvin kite meteorograph pressure calibration data

81. The scale values are plotted against the ordinates on cross-section paper as shown in Figure 22. The plotted points of the "exhaust" should be indicated by "⊙" and those of the "intake" by "X".

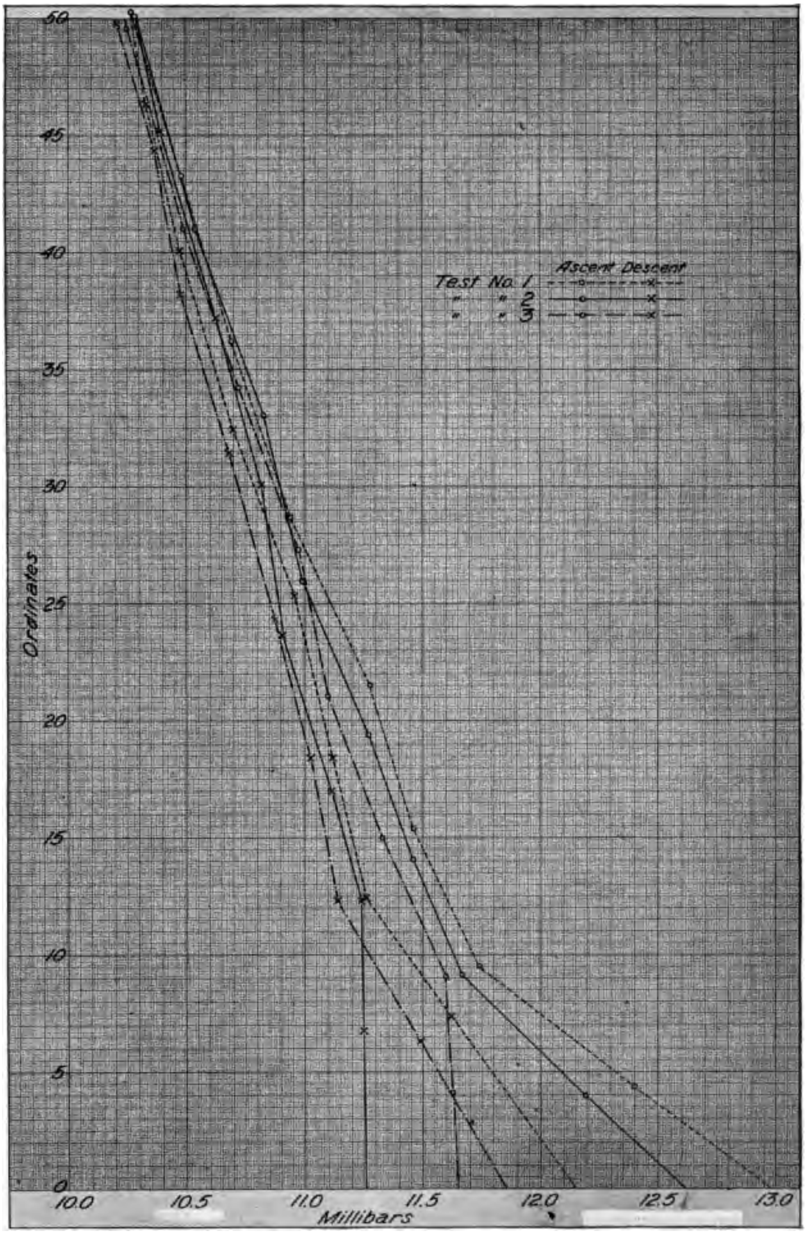


FIGURE 22.—Marvin kite meteorograph pressure calibration curve

82. A "mean" curve is then drawn and is based on the mean of the values indicated by the individual curves referred to above, taken for each 5 ordinates. A table is made up from the mean curve by reading the scale value for each ordinate and interpolating for the intervening tenths. (See fig. 23.)

83. *Temperature calibration.*—This calibration apparatus consists of two well-insulated chambers, one of which can be heated by an electric unit and the other cooled by means of an ice and salt solution. Lower temperatures are obtained by placing the instrument outdoors during the winter season. When outdoors, ample ventilation must be provided, either by allowing the wind to blow through the screening tube or by means of an electric fan. The latter is also used to provide circulation of the air inside these chambers. The meteorograph and a thermometer can be seen through a window.

Ord.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0	1.2	2.4	3.6	4.8	6.0	7.1	8.3	9.5	10.7
1	11.9	13.1	14.3	15.4	16.6	17.8	19.0	20.2	21.3	22.5
2	23.7	24.9	26.0	27.2	28.4	29.6	30.7	31.9	33.1	34.2
3	35.4	36.6	37.7	38.9	40.0	41.2	42.3	43.5	44.6	45.8
4	47.0	48.1	49.3	50.4	51.6	52.7	53.9	55.0	56.2	57.3
5	58.4	59.6	60.7	61.9	63.0	64.2	65.3	66.5	67.6	68.8
6	69.9	71.0	72.2	73.3	74.4	75.6	76.7	77.8	78.9	80.1
7	81.2	82.3	83.5	84.6	85.7	86.8	88.0	89.1	90.2	91.4
8	92.5	93.6	94.7	95.8	97.0	98.1	99.2	100.3	101.4	102.6
9	103.7	104.8	105.9	107.0	108.1	109.2	110.4	111.5	112.6	113.7
10	114.8	115.9	117.0	118.1	119.3	120.4	121.5	122.6	123.7	124.8
11	126.0	127.1	128.2	129.3	130.4	131.5	132.6	133.7	134.8	135.9
12	137.0	138.1	139.2	140.3	141.5	142.6	143.7	144.8	145.9	147.0
13	148.1	149.2	150.3	151.4	152.5	153.6	154.7	155.8	157.0	158.1
14	159.2	160.3	161.4	162.5	163.5	164.6	165.7	166.8	167.9	169.0
15	170.1	171.2	172.2	173.3	174.4	175.4	176.5	177.6	178.7	179.7
16	180.8	181.9	183.0	184.0	185.1	186.2	187.3	188.4	189.4	190.5
17	191.6	192.7	193.7	194.8	195.9	197.0	198.0	199.1	200.2	201.2
18	202.3	203.4	204.4	205.5	206.5	207.6	208.6	209.7	210.7	211.8
19	212.8	213.9	214.9	216.0	217.0	218.1	219.2	220.2	221.3	222.3
20	223.4	224.5	225.5	226.6	227.6	228.7	229.7	230.8	231.8	232.9
21	233.9	235.0	236.0	237.1	238.1	239.2	240.2	241.3	242.3	243.4
22	244.4	245.6	246.5	247.5	248.6	249.6	250.7	251.7	252.8	253.8
23	254.8	255.9	256.9	257.9	259.0	260.0	261.1	262.1	263.1	264.2
24	265.2	266.2	267.3	268.3	269.3	270.4	271.4	272.4	273.4	274.5
25	275.5	276.5	277.5	278.6	279.6	280.6	281.6	282.7	283.7	284.7
26	285.7	286.8	287.8	288.8	289.8	290.8	291.8	292.9	293.9	294.9
27	295.9	296.9	297.9	298.9	299.9	300.9	301.9	302.8	303.8	304.8
28	305.8	306.8	307.8	308.8	309.8	310.8	311.8	312.8	313.8	314.8
29	315.8	316.8	317.8	318.8	319.8	320.8	321.8	322.8	323.8	324.8
30	325.8	326.8	327.8	328.8	329.8	330.8	331.8	332.8	333.7	334.7
31	335.7	336.7	337.6	338.6	339.6	340.5	341.5	342.4	343.4	344.3
32	345.3	346.3	347.2	348.2	349.2	350.2	351.2	352.1	353.1	354.1
33	355.1	356.1	357.0	358.0	359.0	360.0	360.9	361.9	362.9	363.8
34	364.8	365.8	366.8	367.7	368.7	369.7	370.6	371.6	372.6	373.5
35	374.5	375.4	376.4	377.3	378.2	379.1	380.1	381.0	381.9	382.8
36	383.8	384.7	385.7	386.6	387.6	388.5	389.5	390.4	391.4	392.4
37	393.3	394.2	395.1	396.0	397.0	397.9	398.8	399.7	400.6	401.5
38	402.4	403.4	404.3	405.2	406.2	407.1	408.1	409.0	410.0	410.9
39	411.8	412.7	413.6	414.5	415.4	416.3	417.2	418.1	419.0	419.9
40	420.8	421.7	422.6	423.5	424.4	425.3	426.2	427.1	428.0	428.9
41	429.8	430.7	431.6	432.5	433.4	434.4	435.3	436.2	437.1	438.0
42	438.9	439.8	440.7	441.5	442.4	443.3	444.2	445.1	446.0	446.8
43	447.7	448.6	449.5	450.4	451.3	452.2	453.1	454.0	454.9	455.8
44	456.7	457.6	458.4	459.3	460.2	461.0	461.9	462.7	463.6	464.4
45	465.3	466.2	467.1	468.0	468.9	469.8	470.7	471.6	472.5	473.4

Temperature effect on the pressure element, 0.1 ordinate for each 2.0° change, inversely applied.

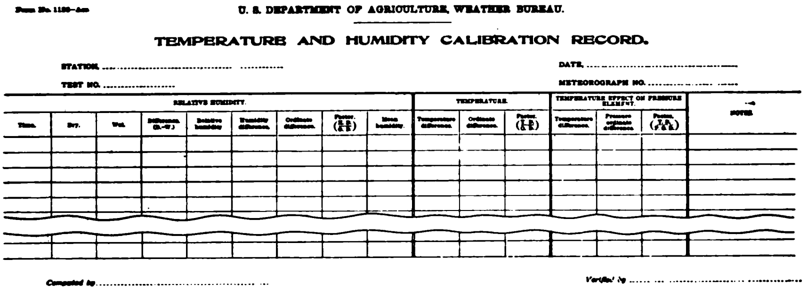
FIGURE 23.—Pressure differences (mb.) per ordinate used in computing kite records

84. Steps of about 15° C. should be made when calibrating the temperature element. The temperature factor is usually linear and

should be between 0.90 and 1.00, i. e., a change of the temperature pen of 1 ordinate should correspond to a temperature change of between 0.9° and 1.0° C. The range of the temperature pen is increased in the same way as the pressure pen, i. e., by moving the link, connecting the pen arm, inward, or closer to the center of rotation.

85. Form 1123 (fig. 24) is used for temperature calibrations and is self-explanatory. The mean of the individual factors is used in the computation of the records. Reasonable consistency must obtain in the individual factors, and when this occurs, about 10 values suffice to give a reliable mean, e. g., five steps between 30° C. and 15° C., and five between 15° C. and 0° C. In general, the instrument should be calibrated for the same range of temperature to be encountered in the free air. This, of course, varies with the seasons and location of the station.

86. It is important to jar the instrument a short time before reading the thermometer during the calibration so that the pen will be properly adjusted. Care must also be taken to see that the temperature remains stationary when the thermometer is being read.



U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

TEMPERATURE AND HUMIDITY CALIBRATION RECORD.

STATION ....

DATE ....

TEST NO. ....

METEOROGRAPH NO. ....

RELATIVE HUMIDITY.									TEMPERATURE.			TEMPERATURE EFFECT ON PRESSURE ELEMENT.			NOTES.
Time.	Dry.	Wet.	Difference (D.-W.)	Relative humidity.	Humidity difference.	Ordinate difference.	Factor.	Mean humidity.	Temperature difference.	Ordinate difference.	Factor.	Temperature difference.	Pressure ordinate difference.	Factor.	

Computed by ....

Verified by ....

FIGURE 24.—Form used in temperature and humidity calibration

87. *Temperature correction for pressure element.*—Since all pressure elements are not entirely compensated for changes in temperature it is necessary to have the pressure pen record when calibrating the temperature element. The pressure pen should be set to record at about 20 ordinates below the top of the pressure space during this calibration.

88. The intermediate temperatures used for calibrating the temperature element should be disregarded when determining the temperature correction for the pressure element and only the extremes used. The differences between the temperature extremes are entered on Form 1123 (fig. 24) and the corresponding pressure differences (ordinates and tenths) are entered in the adjacent column. The correction factor is obtained by dividing the temperature difference by the corresponding pressure change, i. e., pressure ordinate. This correction is usually inverse, i. e., an increase in temperature has the effect of an apparent decrease in pressure, and vice versa.

89. *Humidity calibration.*—This calibration apparatus consists of two copper boxes, capable of being tightly closed. In one, the relative humidity is reduced by means of calcium chloride and in the other it is increased by means of a large sheet of blotting paper dipping into a pan of water. An electric fan in each box provides cir-

culation. The dry and wet bulb thermometers are observed through a window. A small reservoir of water is pushed up through the bottom of the box to wet the muslin of the wet-bulb thermometer.

90. The relative humidity can usually be reduced to less than 10 per cent and increased to 95 per cent or higher, with this apparatus. Intermediate values are obtained by means of an adjustable slot in the side of the box, which permits a change of the air inside.

91. The range of the humidity pen should be from 0 per cent at the bottom of the sheet to 100 per cent at 4 to 5 humidity ordinates (8 to 10 pressure ordinates) above the top of the humidity space. There will be no interference with the pressure pen at high elevations because these pen arms are of different lengths.

92. The meteorograph is usually placed first in the " wet " box and then in the " dry " box. The fan should blow the air through the screening tube and also against the thermometer bulbs. The humidity is reduced by " steps " of 10 per cent (approximately) from the maximum value in the " wet " box to the minimum value in the " dry " box and then increased in the same way. Care must be taken to maintain a constant relative humidity at each of these " steps " when reading the psychrometer. The instrument should always be jarred before each reading so that the pen will be properly adjusted. The " wet " bulb should always be sufficiently moistened.

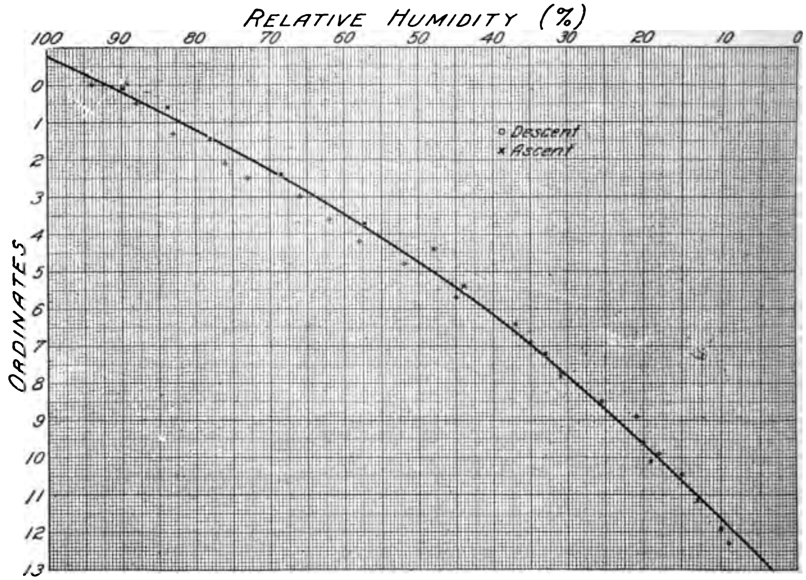


FIGURE 25.—Marvin kite meteorograph humidity calibration curve

93. The humidities are entered at the corresponding points on the record sheet (meteorogram). The accumulated ordinates (to tenths), with reference to the maximum humidity, are determined for each " step."

94. These data are plotted as indicated in Figure 25. In this case it will be noted, that the highest relative humidity obtained was 94 per cent. The ordinates are plotted against the corresponding hu-

midities, zero ordinate corresponding to 94 per cent. A similar chart is drawn for each test, there being usually three made for a new element.

95. Before a humidity scale is made for use in computing the records, it is necessary to adjust these charts for a relative humidity of 100 per cent. This is done by extending the curve to 100 per cent humidity as shown in Figure 25, and noting the ordinate value, i. e., above zero ordinate, where the curve intersects the 100 per cent line. In the present case this is 0.7 ordinate (each division being considered as one ordinate). Another curve is then drawn by placing zero ordinate equal to 100 per cent humidity, and by increasing each ordinate by 0.7. This "mean" curve is based on the several individual curves and is determined by plotting the mean ordinate values, for each 10 per cent of relative humidity, beginning with 95 per cent.

96. Humidity records are computed by means of scales as shown in Figures 26 and 27. The former is called the "standard" scale and the latter the "special" scale. The same "standard" scale is used with all "special" scales, the latter being made for each instrument.

97. The "standard" scale is made up of equal divisions (and tenths) which correspond to ordinates (and tenths) respectively, as read off the meteorograms. The divisions are numbered consecutively upward and downward from a middle "zero," for convenience in determining the corresponding relative humidity for positive and negative (with reference to the base line) ordinates.

98. The "special" scale is based on the "mean" humidity curve referred to above and is constructed as follows: Read the ordinate (to tenths) from the "mean" curve at every 5 per cent interval, beginning at 95 per cent. Beginning at the top of the "special" scale, mark off with the "standard" scale successive intervals of 5 per cent in humidity, equal to the corresponding ordinate values. For example, if the ordinate value of the "mean" curve at 95 per cent is 0.36, then the interval on the "special" scale between 100 per cent and 95 per cent is made equal to 0.36 divisions of the "standard" scale. The same procedure is followed at 5 per cent intervals from 95 per cent to 0 per cent humidity. Each of these intervals is then divided into fifths, to indicate intermediate humidity values.

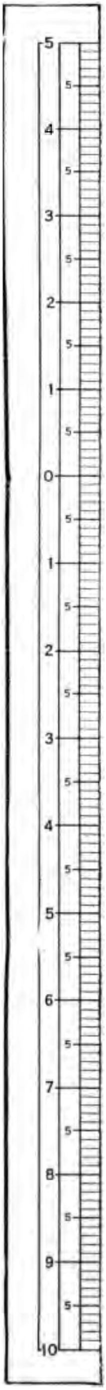


FIGURE 26.—"Standard" humidity scale

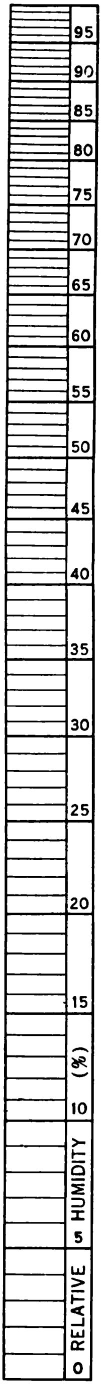


FIGURE 27.—"Special" humidity scale

99. *Wind calibration.*—This is done by attaching the meteorograph to a wind vane so that the wind will always blow through the screening tube. This should not be done in very light or very strong or gusty winds. The instrument should be exposed for several hours and the exact time of "pens down" and "pens up" noted. The number of miles of wind recorded by the anemometer during the same interval should be ascertained, and from these data the value of one complete cycle of the wind pen is determined. (Number of miles divided by number of marks equals value in miles of one mark.)

100. For convenience the scale used at regular Weather Bureau stations for determining wind velocity from Forms 1017 is used for kite records. For this reason it is necessary to multiply the indicated velocity by a factor. This factor is determined from the calibration just described by means of the following formula

$$\frac{\textit{length of record (mm.)} \times \textit{miles of wind} \times 0.447}{\textit{time in hours} \times \textit{number of marks} \times 64} = \textit{wind factor}$$

101. This equation comprises:

(*a*) "Length of record," or the length in mm. of the meteorograph wind record during the interval for which the number of miles of wind was taken from the anemometer.

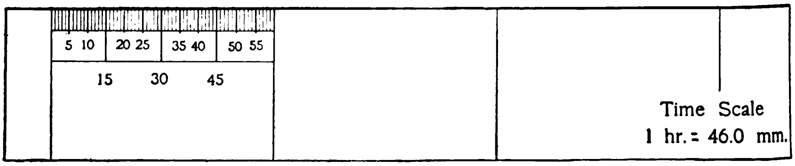


FIGURE 28.—Time scale

(*b*) "Miles of wind," or the number of miles indicated by the anemometer during the interval referred to above.

(*c*) The constant, 0.447, which is the conversion factor from miles per hour into meters per second.

(*d*) The "time in hours" (and tenths), or the interval during which the number of miles of wind referred to above was made.

(*e*) "Number of marks," or the number of complete cycles of the wind pen made during the time interval referred to above.

(*f*) The constant, 64 or the length in mm. of one hour space on Form 1017, for which the wind scale is adapted.

102. Experience has shown that the most suitable wind factors are 0.45 to 0.50 for the northern stations and 0.40 to 0.45 for the southern stations.

103. The factor of a wind element can be altered by changing the pitch of the fan blades.

104. *Time rate.*—The time rate used on meteorograph clocks is approximately 46 mm. per hour, i. e., one revolution in 6½ hours. The rates for individual clocks vary slightly, however, and it is therefore necessary to determine the rate for each clock. This is done by allowing it to run for several hours and dividing the length of record (mm.) by the number of hours (and tenths). From the mean of several such tests a time scale is constructed for use in the computation of the records. (Fig. 28.)

VIII. MAKING THE FLIGHTS

105. For the purpose of forecasting it is desirable to have the kite flights of the various stations made as nearly simultaneous as possible. As a rule conditions for obtaining a good kite flight are best shortly after sunrise. If the flight is started more than one hour after sunrise, the wind in the lower levels often becomes too light to sustain the kites.

106. In view of the importance and value of securing data to the highest elevations possible, every effort should be made to attain the greatest possible altitude without undue risk of a breakaway.

107. In order to make successful kite flights, it is important that the apparatus used in the work be maintained in first-class condition, and that all preparations be made before the flights are started. All the men engaged in the work should become familiar with the handling of the kites, kite wire, tying of various knots, and, in fact, every phase of the work. The men should become familiar with the different sizes of kites used and the weather conditions in which the various sizes fly best. The behavior of the various kites should be noted from time to time, for it frequently happens that there are considerable differences in the flying qualities of kites that appear to be similar in every other respect.

108. The kite that carries the meteorograph is known as the lead or the head kite; the others as secondary kites. It is best to use for lead kites only those that have been previously tried and found to be satisfactory. Of those used as secondary kites, the ones that fly best should be used nearest to the lead kite.

109. Ordinarily, three men are necessary to make a kite flight, but when conditions are favorable, and three men are not available, it has been found that two can do the work satisfactorily; this is especially true when flights are being made during the night. When three men are available, one man operates the reel, another keeps the meteorological record and all notes of the flight, and the third launches and lands the kites, keeps the reel house clean and in order, and assists in other work. If but two men are available, one man operates the reel, and the other keeps the meteorological record. The other work is divided between them as best suited to the occasion.

110. *Carrying the kites.*—When a kite is brought out of the storage room into the open, care should be taken to handle it properly. The man handling the kite should consider the wind velocity and direction. If the wind is light, the kite can usually be handled best by taking a position inside, between the cells, and grasping the bridle stick near the front cell with the right hand and one of the corner sticks with the left hand. If the wind is higher than 6 or 7 m. p. s., the kite can be handled best by taking a position in front of the kite as it lies flat on the ground and grasping the front end of the bridle stick with the right hand and the front end of the upper rib with the left hand. The rear or black cell of the kite is then free to swing around, and care should be taken that it is not damaged by a sudden puff of wind blowing this end of the kite against some obstruction. However, a kite held in this manner with its front end toward the wind can usually be handled without difficulty.

111. A kite should always be held so that the wind will pass through it, and in no case should it be held by any other portion than at, or very near, the junctions of the sticks. When a kite in the open is not needed immediately, it should be placed flat on the ground, in such a manner that the wind can pass freely through it, and held down by weights placed within the cells.

112. *Care of meteorograph.*—The meteorological observer should examine the meteorograph and see that it is in working order before each flight. He should wind the clock, clean and ink the pens, and see that they mark properly. Never draw anything between the pen points except a piece of stiff paper. The shorter pen arms, having less flexibility and describing arcs of smaller radii, should be given slightly more tension than the longer pen arms, in order to allow for the curved surface of the record sheet on the cylinder. Care should be taken that the movements of the pen arms are not obstructed, and that the anemometer is working properly.

113. The meteorograph sheet should be trimmed along the top line and enough cut from its lower edge to allow it to fit snugly between the flanges of the clock cylinder. The sheet should be placed carefully on the cylinder so that the lines meet exactly. In clamping the cylinder in its place the thumbscrew on the right side should be made sufficiently tight; otherwise the cylinder is likely to fall out of place during the flight and the record lost. The meteorograph should be put into its case by grasping the framework between the clock cylinder and the ventilating tube with the left hand and lowering the meteorograph carefully into the case, the case being held in the right hand. The cover of the case should be put on and fastened securely. The meteorograph should then be put into the shelter. Before and after each flight, base-line values should be obtained, the instrument being allowed to record until the pressure, temperature, and humidity pens trace straight lines; for this, an interval of from 5 to 12 minutes is usually required, during which two or three readings of the psychrometer should be made. A reading of the station barometer should be made while the meteorograph is in the shelter both before and after each kite flight. The exact time of putting the pens down should be recorded as the first note of the flight. A complete observation of the surface meteorological conditions should be made at this time and recorded. This observation should include the temperature of the wet and dry bulb thermometers, the direction of the wind, and the amount, kind, and direction of clouds. If more than one kind of cloud is observed, the highest should be entered first.

114. The meteorograph should be tied to the upper rib of the kite a little forward of the center, and it should be braced by four pieces of twine running from the junctions of the sticks at the four corners below. (See fig. 29.) Before releasing the kite the observer should see that the pens are recording and that the clock is running. All of the work done by the meteorological observer, in the way of preparing the meteorograph for the flight and recording the meteorological conditions prevailing at the time of the flight, should be checked by the man operating the reel. Both men should satisfy themselves that the meteorograph is working satisfactorily before the kite is released.

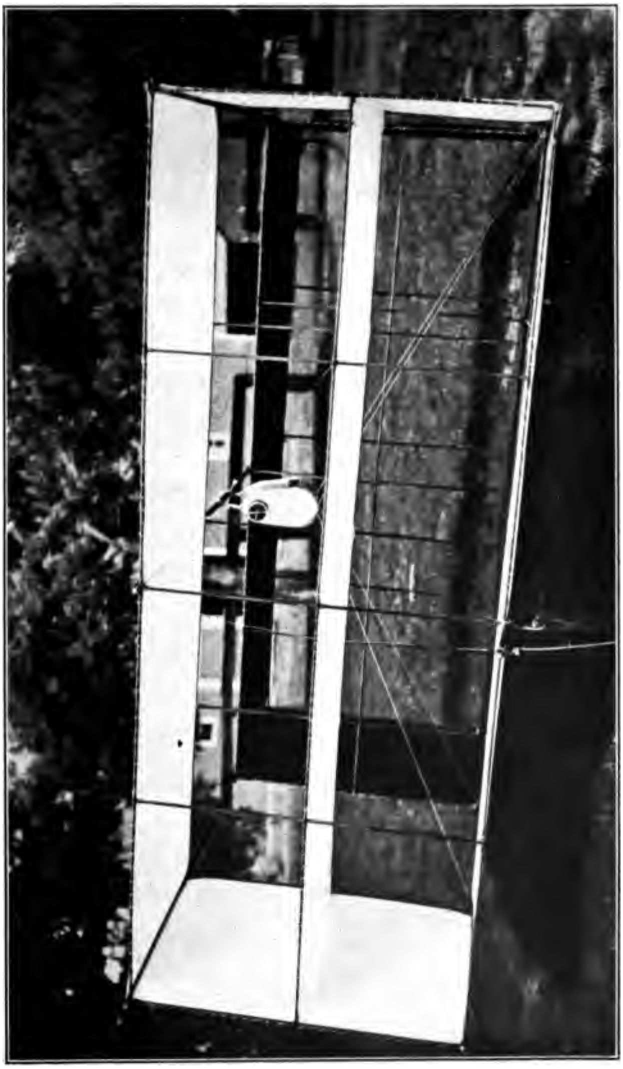


FIGURE 29.—Position and method of fastening meteorograph in kite

115. The bridle and the method of attaching the kite to the line wire are shown in the isometric detail at (*a*) in Figure 13. A strong cord about 18 in. long is fastened to the bridle stick at point 11, and to this is attached a cloth-bound elastic bridle, formed as shown. To the outer end of this bridle is attached another strong cord in the form of a double loop about 18 in. long, having at its end a strong brass ring. This cord extends as shown and is fastened to the extreme front end of the bridle stick. From this point a wire extends back and is fastened at point 14, as seen in Figure 16.

116. The elastic cord used in making bridles is known as shock absorber cord No. 164. It consists of thin strips of rubber about one-quarter of an inch wide tightly bound in a cloth cover, in the form of a small braided rope about ½ inch in diameter. On account of the elasticity of the rubber this arrangement protects the kite and wire from injury by sudden gusts or strong winds by allowing the kite to fly at a smaller angle of incidence, thus diminishing the pull.

117. *The head kite*, which carries the meteorograph, is fastened directly to the line by means of a brass ring in the outer end of its bridle. The secondary kites are flown by means of cords about 125 ft. long. These cords are attached to the main line in the following manner: A piece of No. 9 soft iron wire about 6 ft. long is bent so that a small loop about an inch in diameter is formed near one end. About an inch of the wire at each end is then bent at right angles, thus: └──────────o───┘. This piece of iron wire is twisted tightly about the main line, and the cord holding the secondary kite is tied into the loop.

118. *Launching the kites.*—In taking the kite out for launching, care should be exercised that the wire is not allowed to become slack. The kite should be held by the bridle stick at the rear edge of the front cell with the right hand, and at the lower corner stick with the left hand, as in Figure 30. The man holding the kite should walk out with it held up an at an angle of about 45° with the horizon, keeping a good tension on the wire between himself and the reel all of the time. When the head kite is to be launched in a moderate wind, it should be taken about 60 meters to the leeward of the reel house and released, if possible, while the wind is fairly steady; in a light wind it should be taken out 100 meters or more and pulled up into the air by reeling in; if the wind is strong, the kite should be released while walking away from the reel and should be allowed to go out rapidly, in order to prevent its diving to the ground, or jerking so as to injure the record.

119. Readings called for on the data sheet should be made at the times of launching and landing of kites, when kites enter or leave clouds, and whenever there is a decided change in weather conditions. Wind directions should be given to 16 points. The exact times at which readings of the theodolite are made should be noted, as these are used in checking the altitudes determined from the meteorgraph record. It is not so essential to get other readings precisely at the times noted, e. g., when a secondary kite is launched or landed, the time entered should be the time at which the angle is read, the exact time of the launching or landing being relatively unimportant. While reeling in the first one or two thousand meters of wire, several observations of angle of the head kite and the amount of wire out,

with the usual other readings, except that of the voltmeter, should be made in order to have a record of surface conditions at the time the meteorgraph is at its greatest altitude. When the head kite is within 1,000 meters of the reel, the speed of reeling in should be reduced in order that a good record of inversions and other conditions near the surface may be obtained.

120. Notes should be kept of changes in the kind, amount, direction, and altitude of the clouds. Whenever a kite, either the head or a secondary, enters or leaves a cloud layer, its angular altitude and length of wire out should be noted, as changes in cloud altitude with time are important. However, when the cloud layer does not appear to change much in altitude or structure, only occasional notes of the entry of secondary kites into the cloud base are necessary. Enter notes on all miscellaneous phenomena, such as times of beginning and ending of precipitation, fog, solar and lunar halos, rainbows, thunderstorms, etc. In making notes on the surface record, and in stamping and trimming meteorograph sheets, it is desirable that the work be done in a uniform manner; that is, when several people are doing this work, they should all do it in the same way.

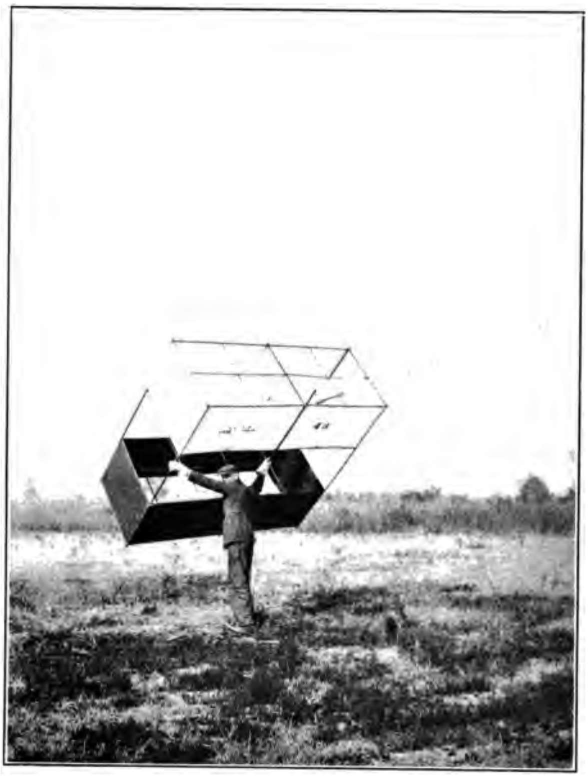


FIGURE 30.—Proper method of holding a kite preparatory to launching it

121. When a secondary kite is to be launched, it is taken out about 50 to 150 meters, depending on the strength of the wind. If the

wind velocity is high, the kite should be let out rapidly after launching, at the same time watching for a chance to get it above the main line. The kites should be let out at such speed that they maintain fairly good angles, but if a kite catches on the main line, it should be let out as rapidly as possible; if it fails to release, it should be reeled in, as many a flight is ruined by a kite caught on the wire. If a kite falls on the wire from above, the "reel" man should stop reeling out and, if necessary, reel in a short distance, in order to allow the wind to lift it.

122. *Landing the kites.*—When a secondary kite is landed, it can usually be brought close to the reel, but in a gusty wind it is best to stop 30 or 40 meters out in order that the wire may respond to the unsteadiness of the wind. The head kite should be landed about 40 to 80 meters out. While it is being run down, the reel man should have the handle on the axle of the reel drum, in order to let out or pull in quickly, according to sudden changes in the surface wind. The head kite should be handled as carefully as possible, as accidents to the head kite nearly always damage the record of the flight. It is generally advisable when landing a kite in a strong wind to pay out line to the kite at the same time the kite is being pulled down. On the other hand, when landing a kite in a very light wind, it is best to walk away from the kite as though to fly it, while pulling it down, as otherwise the mere act of pulling the kite down is liable to cause it to fly almost overhead, and then suddenly "volplane" down to the ground.

123. In the case of breakaways, or the kites falling, or any other accident, complete notes should be made at the time on the surface record sheet. If the kite breaks away the time should be noted and a complete meteorological observation made. The observer should watch the kite through the theodolite [4] as long as possible and record the angles of elevation and azimuth and the time at which the kite disappeared. Every man on the station should be notified immediately and all possible effort should be made to prevent persons and vehicles from running into the wire while it is lying on the ground. The wire should be gathered up as soon as possible.

124. *Kite wire.*—As safe kite flying is so largely dependent on the condition of the steel piano wire used, the utmost vigilance should be observed to prevent damage to it and detect any evidence of weakness throughout its length. When it is necessary to put new wire on the reel or to make splices, it is important that this be done with the utmost care. The wire should never be held by anything but a brass or copper jawed vise. The ordinary steel pliers have rough jaws that make indentations in the wire and weaken it considerably, and should never be used to grasp the wire.

125. Too much emphasis can not be laid on the importance of always keeping the wire taut. After being repeatedly wound on and unwound from the reel drum and over pulleys, and particularly if the wire has been run under tension over wheels of too small diameter, or has rubbed against some solid object, such as the side of the reel house, a fence post, or tree, internal stresses are developed that

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[4] The theodolite used in kite work is of the same design and construction as that used for observing pilot balloons. It is described in detail in Instructions for Making Pilot Balloon Observations, Weather Bureau Circular O, Section II.

will cause the wire to coil as soon as it is slackened. If, on again tightening, a single coil becomes a kink the wire will break. The tendency to coil varies inversely as the diameter of the wire, and it is therefore advisable to feel out the smaller sizes of wire frequently when reeling in or out.

126. Opportunities for the wire to slacken sufficiently to coil are always present when flying in light winds, and when, under such conditions, it becomes necessary to reel in rapidly to assist in raising the kites, the reel should always be slowed down gradually before coming to a stop, if conditions permit. Rapid reeling out in a light wind, especially when pronounced convection currents are present, will often cause coiling and probably kinking of the wire. With a wind barely strong enough to sustain the kites in the air and convection currents prevailing, a wavelike effect is often observed, the kites rising and falling in succession. Then, if wire is paid out rapidly to the rising kite, the wire between it and the falling kite immediately in advance will slacken and probably coil.

127. Another common source of damage to the wire is faulty wrapping of the heavy branch wire used to attach secondary kites. Under the direction of an experienced man a novice should learn how to attach this wire without leaving permanent sharp bends in the piano wire. Occasionally this branch wire should be shifted a few meters[5] from its usual position on the line. When, after landing a secondary kite, it is found that the cord is wrapped around the main line, care should be taken not to pull the cord too hard in the attempt to unwrap it, as this causes an injurious twisting strain on the wire. In an emergency it is better to cut the cord than to try to unwrap it hurriedly.

128. The wire should be kept clean and slightly oiled. Incrustations of ice or rime should be wiped off when reeling in, and the wire again wiped with a piece of oiled waste when reeling out in the next flight. This wiping of the wire should be frequent; it not only serves to prevent rusting, but also, prevents kinks from passing by unnoticed. Few breakaways are caused by the pull exceeding the normal tensile strength of clean undamaged wire. Kinks, sharp bends, rust spots, or flaws in the splices cause the majority of accidents.

129. *Observation and experience.*—After having acquired training in the practical details of kite flying, the beginner should supplement his knowledge as soon as possible by close observation of weather conditions during kite flying, and a study of upper-air records.

130. It should be the aim of the kite flying force to obtain the highest possible flights consistent with safety under various weather conditions, to preserve the continuity of daily flights for as long periods as wind and weather permit, and to reduce breakaways and other accidents to a minimum. All the competency of the force derived from experience and study will be needed to bring about these results.

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[5] Ordinarily, the secondary kites are attached at more or less regular intervals from the head kite—e. g., 500, 1,200, 2,000 meters, etc. Thus, there is a possibility of weakening the kite wire by repeated wrappings of the "splice" or galvanized-iron wire at the same place.

131. Because of ever-changing weather conditions with which the kite flyer has to contend, it is evident that, except in a general way, no set of rules can take the place of experience. Much of what follows has a general application, and while many of the situations relating to weather conditions and kite flying should be taken with the reservation that they apply more strictly to the Middle West, it is felt that a discussion of them will serve the useful purpose of guiding the interested beginner into the proper channels of observation and study. On the whole, the experiences met with in kite flying in different portions of the country are undoubtedly similar enough in many respects to justify some general rules or suggestions.

132. To the interested observer, a day-to-day comparison of the upper-air records with the weather map offers an unlimited field for study. As ordinarily the aerological stations do not have available current weather maps, it is desirable that the observers make a study of local weather conditions, chiefly the record from the barograph, the observations of clouds, the kite records, and the weather maps that are received, and correlate these with the view of ultimately being able to anticipate to some extent upper-air conditions from local indications alone. For example, it is well to follow the progress of the barograph from day to day, and thus try to grasp the sequence of HIGHS and LOWS, and their approximate relation to the station. The early morning pilot balloon observation is of great value in connection with kite flying, in that it gives an accurate measurement of wind conditions at various altitudes and thus assists materially in determining the number and sizes of kites to be used Obviously such observations are limited by the height of the lowest cloud layer, but nevertheless they give valuable information as to the wind speed at any height below that level.

133. Accuracy of record and good judgment in observation are essential to a logical interpretation of the kite records. Opportunities for observations leading to important deductions in meteorology occur frequently in kite flying, apart from those that make a par of the routine record. Initiative and alertness in work and observation are therefore valuable assets in the field.

134. Discrimination should be used in those instances in kite flying that permit latitude of opinion. An example is the case of determining the direction of the wind aloft. This should be ascertained not only by observing the apparent direction of the head kite from the observer and from the other kites, but also by the position of the kite in the theodolite (assuming that the head kite flies straight) and by whatever horizontal movement it may have. The observer should familiarize himself with the appearance of the kite in the theodolite at close range, in order that he may, when necessary, associate an angular appearance of the kite in the theodolite with direction of the wind in which it is flying. When the kites make a large "swing" during flights, a careful comparison of the apparent directions aloft recorded when reeling out with the apparent directions at corresponding altitudes when reeling in, will, to a large extent eliminate the possibility of error. As it is often difficult to determine actual directions of the wind aloft at night and when the kites are obscured by clouds, experience should be directed toward observing the relation between the azimuth of the wire as it leaves the reel and the direction aloft.

135. *When to reel in.*—The observer should memorize the values of the sines of angles commonly recorded with the theodolite, thereby enabling him to compute approximate altitudes quickly when necessary, and to keep constantly in mind the relation between the altitude of the head kite and the amount of wire out. So long as the head kite maintains a fairly steep angular altitude (say 30° or more) it may be assumed that the pull is at its maximum and that, barring a change in the weather conditions, reeling in will not throw the kites much higher nor materially increase the pull. Such a flight may be considered a normal one, and the number of kites to use and the distance to reel out will be clearly indicated by the dynamometer.

136. Ordinarily, the final reeling in should commence when the stationary pull shows indications of passing 200 lbs. Also, more kites should not be launched after the dynamometer reads between about 160 and 200 lbs., this also depending on the number of kites already flying. A little computation will generally settle this point. For example, when the pull of two kites is 150 lbs., another kite is likely to increase the pull to 225 lbs; while a pull of 175 lbs., with seven kites, will probably not be increased to more than 200 lbs. by the addition of another kite. The same reasoning should be used when estimating the probable result of reeling in, or of an increase in wind. Given a certain pull, it is obvious that reeling in or an increase in wind will augment that pull in proportion to the number of kites used. The tensile strength of the different sizes of wire used should be kept in mind (see Section IV, paragraph 29), and precautions taken to avoid, as far as possible, taxing any of the wire to more than two-thirds its normal capacity.

137. *Number of kites to use.*—Decision in the matter of number of kites to use should also be influenced by the possibility of the kites ascending into a decidedly stronger wind aloft with further reeling out. The winds normally increase with altitude, but occasionally this rise in velocity is much more rapid or abrupt than usual. Indications of an abnormal increase in velocity with altitude will usually be apparent to the careful observer by the action of the dynamometer, the movement of whatever clouds may be present, the results of the preceding pilot balloon observation, and especially by the tendency of the head kite to maintain or even increase its angle when reeling out.

138. As long as the kites maintain a good angular altitude, there should ordinarily be but little difficulty in making an excellent flight without subjecting the wire to excessive pull. If, however, there is much wire out with many kites and the angle is low, success and safety will necessitate a rather tedious program of work. Under such circumstances, reeling in might raise all or most of the kites to such higher altitudes and stronger winds as to increase the pull to the danger point. It will then be advisable to sound the strength of the upper winds by occasionally reeling in a few hundred meters before putting on additional kites, meanwhile watching the head kite through the theodolite. If the trial reeling in is not successful in permanently raising the kites, a note should be made, mental or otherwise, of the depth of the light wind. Eventually decision should be made whether to reel in all the kites and rearrange them with a view to greater lifting surface by using more or larger kites,

or to continue the flight with the expectation of finally lifting them into sufficiently strong winds aloft.

139. After an altitude of between 2,500 and 3,000 meters has been sounded without indications of strong wind it is probable that no wind of dangerous strength will be encountered to an indefinite height. When an altitude of about 3,000 meters has been reached, with only a moderate pull and a good angle, experience has shown that still higher altitudes may generally be obtained by adding more kites and reeling out farther, without materially increasing the pull. This may be explained by the tendency of light wind to extend to high altitudes, and the fact that actual increase of velocity with elevation is to some extent offset by the diminishing air density.

140. The circumstance of kites flying at a low angle is often associated with a stratified condition of the air, manifested by a brisk shallow wind, on top of which the kites seem to float as though on a liquid surface, apparently in a calm and all flying at about the same altitude. This condition may be met with in winds from any direction; and except in easterly winds (for reasons explained later), requires the exercise of caution lest too many kites be launched and exposed to the danger of a rise into winds too strong for the wire. The danger is to some extent proportional to the proximity of the lower winds to a westerly direction, being at a minimum in easterly winds, and at a maximum in winds between northwest and southwest. When kites rise above such a calm stratum they will as a rule enter a wind from some westerly direction, and cause a pull at the reel that will be partially a resultant of the direction and amount of the pulls of the individual kites.

141. Kites floating above a shallow wind, other than easterly, can generally be reeled up into higher winds aloft after four or five kites have been launched on a few thousand meters of wire. With easterly winds, however, the change in direction is often so abrupt, and of such angular magnitude in comparatively short intervals of altitude, that repeated reeling in will be useless. In such a case the final ascent of the leading kites into stronger upper winds can often be accomplished by exercising patience. With easterly winds near the ground and westerly winds aloft, it has been observed that the kites will more often show a tendency to shift to the right than to the left as they rise above the lower strata. This shifting is generally slow and will not result in raising the kites until the upper portion of the wire is approximately in line with the drift of the upper winds. The total change in azimuth from the surface wind to the direction of the highest kite may be as much as 200°.

142. A stratification of the air, causing the kites to apparently "float," is quite common, and is due most often to abrupt, though not necessarily large, changes in wind direction with altitude. Sometimes a stratum of comparatively calm air intervenes between two winds having nearly the same direction, in which case it is probable that the stratification is related to abrupt changes in temperature and humidity.

143. Veering of winds with altitude averages greater than backing both in frequency and angle, and is characteristic of approaching LOWS and retreating HIGHS. Backing of winds, associated with retreating LOWS and approaching HIGHS, is usually more gradual, and

in the case of retreating LOWS, is sometimes preceded by veering in the lower levels. The amount of shifting in wind direction with altitude has an important bearing on the number and size of kites that can safely or advantageously be used. The accuracy with which this distribution of the winds can be forseen will depend largely on the accuracy with which observations of cloud direction and velocity are made.

144. Easterly winds as a rule should occasion no anxiety to the observer from the standpoint of excessive pull, unless complicated by heavy rapidly moving clouds. This assurance of generally safe conditions in easterly winds may not, however, apply to other than interior sections of the country. In the Middle West it has been found that deep east winds are nearly always light to some unknown limit, and that when strong easterly winds occur, they either diminish with altitude or are rather uniformly strong with altitude. In the latter case, the number of kites to use is easily apparent. The condition of light easterly winds surmounted by strong easterly winds is probably rare. While in the case of kites swinging from lower easterly winds to upper westerlies a strong current from the latter direction may be encountered, it is likely that the pull will not be excessive, owing to the more or less opposing pull of the kites.

145. *Weather types.*—A few flights will convince the observer to what extent success in kite flying is measured by ability to anticipate conditions. Considerations of pressure rank first in making deductions of probable upper-air conditions and should be judged somewhat as follows: The state of the barometer, whether rising, falling, or stationary, and whether above or below normal; the duration and magnitude of the rise or fall; and the probable geographic distribution of the pressure.

146. Changes in the surface wind are inclined to be synchronous with changes in pressure and the velocities themselves proportional to the pressure gradient. This relation between the surface pressure and wind is not so simple when applied to velocities aloft. It will often be found that surface winds alone fail as an index to the probable velocities aloft and that they should be considered in connection with the previous few hours' pressure record. It will often be necessary to wait until the first kite has ascended a few hundred meters before coming to a final decision as to what conditions to expect.

147. A pronounced condition that has been repeatedly found in the Middle West, and that probably occurs in some modified form over the greater portion of the country, is that which accompanies a period of rising pressure when the pressure is already high. During the period of rising pressure strong winds, often increasing with altitude, will usually be found, while the least indication of flattening out of the barograph trace seems to be followed by diminishing winds—near the ground first, and progressively later at higher altitudes. The height to which the strong winds extend varies according to the structure of the HIGH and the intensity of the preceding LOW. While, without the aid of current weather maps, it will not ordinarily be possible to estimate the intensity of the pressure gradients surrounding the station, a knowledge of these facts, together with what-

ever telegraphic information is available, will be helpful. If a fligh has been started while the pressure is rising steadily, and the pul soon reaches the limit of safety, it will sometimes be found advantageous to apply the brake and wait, an hour or more if necessary, until the expected stable pressure, with its attendant abatement of winds, makes further reeling out possible. The higher the pressure the more likelihood there is that it will soon reach its crest. Periods of rising pressure are often accompanied by stormy weather, more especially while the pressure remains low. The barograph and wind-register record should then be watched, as well as the weather, in order that the most opportune time for starting a flight may not pass by. Under these conditions the pressure will sometimes stop rising simultaneously with, or soon after, the ending of precipitation and the wind become too light to launch a kite.

148. After the pressure becomes high and stationary, the winds will be light to moderate to considerable altitude, their average strength depending on a number of factors, chiefly the area and magnitude of the HIGH and the position of its crest, and the intensity and distance of the surrounding LOWS. The surface wind may then be too light to launch a kite until the pressure has begun to fall. Occasionally, though, a temporary interruption of the stationary pressure may strengthen the surface wind sufficiently to start a flight—a circumstance the observer should be on the alert to take advantage of.

149. If a flight has been started after a more or less continuous fall in pressure has set in, increasing winds may be expected during the progress of the flight. The velocity to which the winds will rise in any given time will depend not only on the rate of fall in pressure, but also on the pressure itself. It will generally be found that the greater the magnitude of the retreating HIGH the longer will the maximum intensity of the approaching LOW be delayed. On the other hand, a slowly moving HIGH, even though it be comparatively flat, appears effectively to delay the advance circulation of a following LOW. Shallow winds, above which it is difficult to raise the kites unless much lifting surface is used, are common in the rear of HIGHS.

150. If the pressure is low and stationary, the surface winds may be light, and under such circumstances one should resist the temptation to use large and many kites until the preceding fall in pressure has been ascertained. If the fall has been very slow and no ver low level reached, this, together with the light surface winds, ma be construed as indicating comparatively light winds to a fairl good height. If the pressure is quite low and the preceding fall ha been rapid, a more or less sudden rise in velocity may be looke for at some not very great altitude; or may accompany a sudden shi in direction.

151. If a flight is made during a period of rapidly falling pre sure, and the pressure is below normal, the winds will very likel be strong practically from the ground up; in this case, if a flig is possible, it will naturally be limited to few kites. Ordinaril strong winds do not preclude the possibility of a flight unless the attain gale force near the ground. Where the strength of the win limits the number of kites to three or less, flights to nearly 3,00

meters above the ground may be obtained by rapid reeling out and without risk of materially increasing the pull on the reel-in since, as explained elsewhere, the Marvin-Hargrave kite is self-adjusting to strong winds. In such a case care should be taken not to reel out more wire than the kite can hold above the ground, bearing in mind that the wire will drop to a lower angular altitude as soon as reeling in commences.

152. When the barometer is low and rising, the winds are likely to be more uniform in direction and velocity with altitude, and less given to abrupt changes, than when the pressure is low and falling. Much the same precautions should be observed in either phase of low pressure, although in the case of rising pressure there is smaller probability of the pull increasing after the highest possible altitude has been attained. On the whole, it may be said that falling pressure presents more difficulties than rising pressure. Low pressure, owing to the complexities of cyclonic circulation, has more elements of danger than high pressure.

153. While the different conditions of pressure met with from day to day are, of course infinite in number, their relation to the probable velocities may be summed up as depending on the barometric tendency, and the position of the centers of high and low pressure areas. The latter qualifying circumstance is the most difficult to make deductions from, in the absence of current weather maps, and all available sources of information should therefore be studied carefully to determine the probable direction from the station of a near-by center of low pressure. When the direction of movement of a LOW coincides with the direction of the gradient winds, there is evidence that winds at the various altitudes average strongest, other things being equal, and that when such a condition is impending the rise in velocities will be most rapid. The trend of the isobars can be estimated closely from the surface winds, the barograph trace, and the aspect of the first kite launched after it is a few hundred meters high.

154. In estimating the probable direction of the centers of high and low pressure from the station at the beginning of a flight, in the absence of other information, the observer should supplement his knowledge of the general laws of surface circulation with observations of the wind direction a few hundred meters above the ground. Unless surface winds are quite strong and have blown from a certain direction for some time they do not give conclusive evidence of the direction of the pressure gradient, owing to the susceptibility of light winds to local topography and diurnal change in temperature. Judgment will therefore have to be deferred until the behavior of the first kite launched has been observed.

155. With a little practice, conclusions concerning the pressure distribution can be arrived at that will be accurate enough for the purpose of kite flying. This refers more particularly to the cold season, when pressure conditions and changes are sharply defined. With approaching warm weather the whole problem of analyzing pressure conditions becomes increasingly difficult; and unless some telegraphic information is available, one will often be at a loss to know what to expect. This has its compensation, however, in the comparative freedom from unsafe conditions, except such as are of a local nature, in summer weather.

156. The trend of the isobars can be approximated by considering the direction of the wind at that moderate altitude above the ground where surface friction is surmounted and to which the kites gradually veer. In LOWS and in the rear of HIGHS, gradient winds will usually be found at only a few hundred meters above the ground. While their direction with reference to the isobars varies somewhat with the rate of movement of the LOW or HIGH and their depth varies considerably in different quadrants, it will be of aid to know when these gradient winds have been reached, considering that their direction is approximately parallel to the surface isobars, with low pressure to the left. Above these gradient directions the winds in a LOW will ordinarily veer or possibly back to the higher levels, depending on whether the LOW is approaching or receding. In the front of a HIGH the winds will often back from the ground up, no veering being apparent at any level.

157. *Clouds.*—Low-lying dense clouds add to the perplexities of kite flying. They are likely to be a menace in any wind direction and during any season of the year, more especially, however, with low pressure prevailing. Stratus clouds are characteristic as trouble breeders, and any indication of strato-cumulus blending into stratus should be reason for caution; and conversely, stratus breaking into strato-cumulus should be considered encouraging. It is desirable, of course, to obtain a record of upper-air conditions in any cloud condition, but judgment should be used in deciding on the number of kites to expose when conditions seem threatening. In warm weather dense stratus are not necessarily dangerous unless they are moving rapidly and rain is falling or seems imminent. The combined effect of rain and strong wind often completely crushes one or two kites. It will sometimes tax the initiative of the flying force, when caught in such conditions, to limit the danger to one or two kites and avoid excessive pull on the wire. If a flight is started during the prevalence of such conditions, reeling out and the launching of kites should proceed cautiously until the absence of any strong wind in the cloud layer is assured.

158. During periods of more or less continuous rain, the most opportune time for making a flight without risk of the kites collapsing appears to be about midday, when evaporation from the clouds often causes a lull in the rain.

159. Dense fog usually occurs with light surface wind. It has been the experience of the writer, in the Middle West, when flying in dense fogs, that if the wire and dynamometer show that the kites have entered a stronger wind of different direction a few hundred meters above the ground, it can be taken for granted that the fog sheet has been surmounted, and need give no further concern. In other conditions of fog, the kites will fly at a low angular altitude, become water-logged and heavier, and eventually fall to the ground, unless reeled in soon after the flight has been started. A useful precaution to observe when the kites are flying at a low angle in a fog is to take frequent readings of atmospheric voltage, in order to watch for the possibility of the wire touching the ground.

160. *Ice formation.*—In the cold season of northern latitudes an additional difficulty connected with flying in heavy clouds lies in the accumulation of ice or rime on the kites and wire in amounts

that may be sufficient to cause them to fall in spite of rapid reeling in. This danger is present only when the surface temperature is in the neighborhood of freezing or somewhat below. When any of the lower types of clouds prevail with this state of temperature, a certain amount of ice will almost always form on the wire, but excessive deposits on wire and kites will occur only when the sky is overcast or nearly so, and the circumstances favor a prolonged exposure of the clouds. The deposit is caused by minute globules of the subcooled water, sometimes having a temperature as low as −10° C., freezing on contact with the solid surfaces—a process that is facilitated by wind. There is but little danger of more than a light coating of ice on the wire when snow is falling freely, but moist snow with wind may cause an excessive pull in the same manner as rain with wind.

161. If, after rising above a strong surface wind, the kites float on top of or in the clouds, this fact will be indicated by the dynamometer. With freezing temperature, unless the kites can be thrown up higher by reeling in, accumulation of ice will proceed over a long approximately horizontal line of kites and wire and gradually cause them to settle down. A common condition attending a period of rising pressure in winter is a strong cold under-running northerly wind, near the summit of which dense clouds form. Often the wind above the under-running cold current is too light to lift the kites free of the influence of the clouds, with the result that the heavily laden kites will fall into the strong lower wind and cause excessive pull. If the dynamometer indicates that the kites are flying at a good angle, a condition of great cloud depth may be present, the possible consequence of which will be indicated only by a lowering in the angle of the wire and a lessening of whatever atmospheric electric potential might previously have been recorded. A normal potential will dwindle almost to zero as the wire becomes increasingly bulky with ice or rime and lower in angle. Dynamometer readings can be relied upon only to indicate the approximate angle of the kites before they and the wire have had time to become heavily coated, after which the pull is inclined to be deceptive, owing to their increased weight enabling the kites to present a more nearly normal surface to the wind.

162. When in the judgment of the observer the conditions seem to be favorable for the formation of ice or rime on the wire, it is a good plan to reel out as rapidly as is consistent with a good ascensional rate of the kites, thereby penetrating the cloud layer with minimum exposure thereto. A good rule to observe in any threatening cloud condition is to begin the final reeling in when the pull is well on the safe side of 200 lbs. in order to leave a margin of safety for any possible increase in pull later on.

163. The fact that deposits of rime (frostwork) on the wire, which have been observed as large as half an inch in diameter,[a] are most pronounced when snow is not actually falling, seems to indicate the lack of some final stage necessary for precipitation, when all the other essentials for condensation are present. An interesting circumstance bearing on this point is the evidence, in numerous records of

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[a] Mo. Wea. Rev. Supplement No. 10 (Aerology No. 5), p. 5.

kite flights, that the beginning of precipitation is often preceded or attended by a sudden increase in the electric charge on the wire.

164. *Diurnal series.*—A knowledge of pressure distribution over the country is of considerable help when attempting to make 24 to 36 hour series of flights, as the series are often ended or interrupted by the wind becoming too light or too strong, or the weather becoming stormy. There are a number of conditions that have been observed at Drexel (near Omaha), Nebr., to be favorable for the steady winds and fair weather desirable for an unbroken series of flights of fairly uniform altitudes. These conditions are perhaps typical of considerable of the interior portion of the country.

165. An area of high pressure receding to the east generally causes a prolonged, somewhat vigorous drainage of air from a southerly direction in the lower levels, and more or less steady, lighter winds from a westerly direction in the higher levels. If the pressure is quite high and the surface wind is strong enough to begin a series while still in the crest of the HIGH, or as soon as the pressure begins to fall, the probabilities are for favorable flying weather for 24 to 36 hours or more.

166. An area of low pressure, centered north of the station and moving eastward, is often attended by generally fair weather and continuous moderate southerly winds in the lower levels. At higher levels, the winds will probably be strong and veer from southwesterly to westerly or northwesterly, as the LOW drifts eastward.

167. In the winter excellent series of flights are possible when a pronounced high-pressure area is approaching from the west or northwest. In this condition, however, a series may have to be started while the weather is still cloudy, in order to obtain at least 24 hours continuous record, since the crest of the HIGH, with its attendant light surface winds, often comes not long after the weather clears.

168. *Thunderstorms.*—Since a thunderstorm is largely a local phenomenon, no general rules can be laid down for detecting its approach. No precaution seems ordinarily of avail other than listening attentively for thunder on days when conditions seem to favor thunderstorm development, and frequently breaking the electrostatic ground for evidence of "flash" discharges. By "flash" discharge is meant a momentary increase in the potential that causes intermittent sparks at the ground gap and are synchronous with discharges of lightning in the vicinity. As such irregular discharges may be an accompaniment of storms passing the station as well as of one approaching it, and are, moreover, often observed when the sky is mostly clear, they are not, in the majority of cases, necessarily a warning of unsafe conditions. Flashes of lightning on the horizon should be considered in connection with the observed drift of such clouds as are visible. The probable course of the outlying storm may thus be determined.

169. A possible indication of thunderstorm development may be inferred from the strong vertical currents of great depth that are frequently evident in warm weather during kite flights. If these are associated with high surface humidity and increasing Cu. or St. Cu. clouds, conditions are probably favorable for thunderstorm formation. In general, when the sky is overcast during the warm

season, an erratic action of the electrostatic voltmeter, or thunder, should be considered a warning.

170. Flights have on a number of occasions been caught in thunderstorms, and, while the records during such storms are extremely valuable, the danger of personal injury and damage to equipment is too great to justify other than unavoidable flights under such conditions. The danger to the person in thunderstorms lies chiefly in the landing of secondary kites. The precautions outlined in paragraphs 23 to 27, inclusive, should be heeded.

171. *Local conditions.*—The continuity of daily flights will depend a great deal on the vigilance and energy of the station force, as on many days when comparative calm prevails a brief interval of breeze will be sufficient to carry the kites into steady sustaining winds aloft.

172. Although surface velocities are higher in daytime than at night, this fact, particularly in warm weather, has often the opposite significance in kite flying. This is undoubtedly explained by the fact that convectional currents, even though they may cause a slight acceleration of surface movement, have a damping influence on the normal increase of wind velocity with altitude, and, moreover, constitute a mechanical hindrance to successful launching of kites. Strong convectional currents tend to cause continual confusion of kites, cords, and wire. This sometimes becomes so aggravated as to necessitate reeling in to prevent the kites from falling to the ground. Flights, therefore, should be started early enough on summer mornings to assure a height of 1,000 m. or more before convectional currents are well under way.

173. Sometimes on clear, quiet days, during which a flight has been impossible, the kites will readily go up about sunset, or when nocturnal cooling sets in. It completes the often-observed paradox, just mentioned, of flying conditions and surface wind, as in such instances the station anemometer is very likely to record lower velocities than at any time during the day. A plausible explanation is that the sudden cessation of convection currents permits the normal tendency for horizontal air movement to come into play and that the intense radiation at that hour confines the stagnant air to those very lowest levels immediately above the ground. At Drexel this condition has been frequently observed and taken advantage of, although it has been found to be decidedly perculiar to south winds.[7]

174. The foregoing paragraph illustrates one of the many causes that operate to mask the possibility of a flight from indications of the station anemometer. Notwithstanding that it requires a velocity of at least 5 m.p.s. to sustain a kite and several hundred meters of wire, surface velocities as low as 1.5 m.p.s. need be no discouragement to those attempting a flight.

175. *Breakaways.*—Experience in kite flying will be valuable in the measure that it develops not only prescience of danger but confidence in action when doubtful conditions obtain. Overcautiousness may spoil or curtail many a flight that would otherwise have been safe and high. On the whole, it may be said that dangerous conditions for kite flying, apart from those that are clearly evident

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[7] See Mo. Wea. Rev., Supplement No. 8 (Aerology No. 4), p. 7, and Mo. Wea. Rev., June, 1919, 47:373.

from surface conditions, are exceptional. Therefore, whenever weather conditions on the ground permit, a flight can generally be started with all assurance of safe return of the kites.

176. Breakaways may be divided into two classes—(*a*) accidental and (*b*) those caused by overloading the wire. The former may be largely prevented by attention to the condition of the wire, while the latter may be subdivided into a number of causes as follows:

1. Kites floating on top of a shallow wind or flying at a low angle and finally rising into strong wind aloft.
2. Reeling out too rapidly to permit the dynamometer to show increase in velocity aloft.
3. Wind increasing rapidly soon after beginning to reel in.
4. Too long exposure of kites to damp, fast-moving clouds.
5. In rarer cases, kites caught in a thunderstorm or sudden squall.

177. To these may be added the occasional risk of kites falling on account of accumulations of ice and the unsteady effects of light winds or convection currents.

178. The prevention of trouble from all these causes will, to a large extent, be under the control of the field force. Cause 3 will call for the greatest caution on the part of the observer in charge of the flight. Winds increasing during the progress of a flight generally accompany falling pressure. The rise in wind velocity attending the approach of a low-pressure center has often been observed to begin at some moderate altitude and subsequently become more general. Close attention to the dynamometer while launching secondary kites will give early evidence of increasing wind force aloft.

IX. REDUCING THE RECORDS FOR TELEGRAPHING

179. The data should be prepared for telegraphing and dispatched with the least possible delay after the completion of each flight.

180. The telegraphic data are obtained by means of an Adiabatic Chart. (Fig. 31.) A detailed description of the theory and preparation of this chart has been published in the Monthly Weather Review, November, 1926, and therefore is not included here. Since July 1, 1930, the Weather Bureau has substituted the use of Adiabatic Charts for the more detailed computations described in Section XI, for all except sounding balloon observations. For telegraphic purposes it is not necessary to enter the wind or vapor pressure data on this chart. Only the "ascent" portion of the records will be telegraphed.

181. The kite report will be coded in the following manner:

(*a*) The first word in the message will be the name of the station.

(*b*) The second word will indicate the time (local standard) of launching the head kite. This will be given to the nearest hour, zero to 24. Example: 6.25 a. m. (six); 9.30 a. m. (ten); 2.30 p. m. (fourteen); 7.37 p. m. (twenty), etc.

(*c*) The third word will give the surface temperature (° C.) and relative humidity at time of launching. This word will be taken from the "Pressure-Temperature" words, pages 24 to 33, Weather Code (1924). Familiarity with the latter is assumed. Example: 14.6° C., 49 per cent, FULGOR. It will be noted that the decimal in the temperature is first disposed of according to the regular

Weather Bureau rule and this value (15) is then doubled (30). This makes is possible to send odd temperatures. The humidity is indicated in the second syllable, the odd value (49) being first changed to an even value (48). Negative temperatures are likewise doubled (*after* disposing of the decimal), and the complement then coded, as above. Examples: −3.5° C., 89 per cent, TARSOAP; −1.3° C., 56 per cent, TOMINA; 0.8° C., 99 per cent, ATOM; 0.2° C., 82 per cent, USAGE. In order to avoid possible confusion between relative humidities of 0 per cent and 100 per cent, the former value will always be coded as 2 per cent.

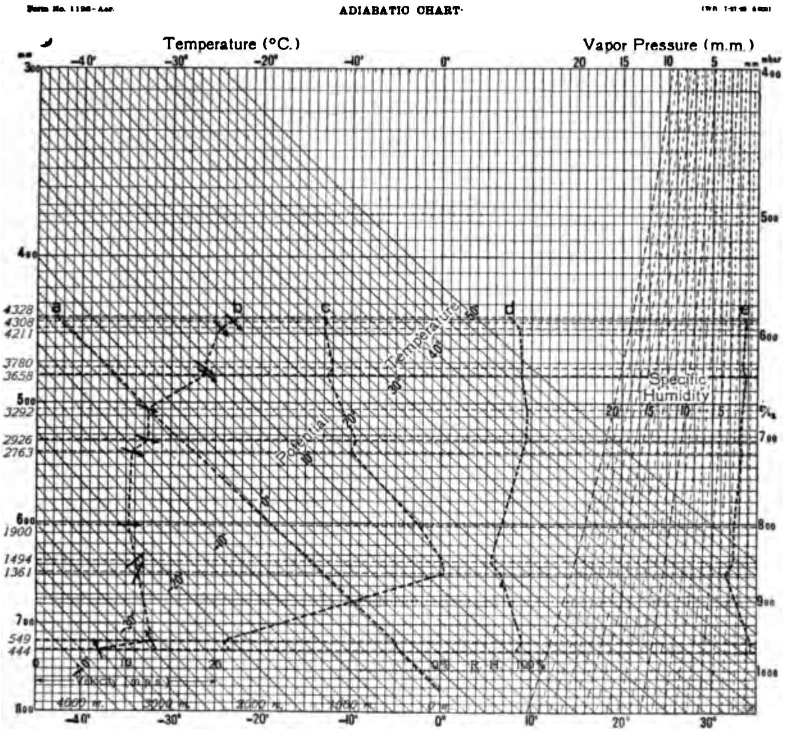


FIGURE 31.—Graphical representation of kite record from Ellendale, N. Dak., February 2, 1925. (*a*) Pressure-height curve referred to height scale along abscissa axis; (*b*) pressure-wind curve, showing velocity and direction; (*c*) pressure-temperature curve; (*d*) pressure-relative humidity curve; (*e*) pressure-vapor pressure curve. Figures along ordinate scale on left side are obtained from pressure-height curve, and indicate the altitudes of the points at which the lapse rate changes. Small vertical lines on the even pressure lines indicate amount of correction to be applied to actual temperature to obtain virtual temperature. Broken lines running upward along right side of graph are specific humidity curves. Upper right abscissae are vapor pressures. Diagonal full lines from lower right to upper left are dry adiabatics, and give the potential temperature (°C.) referred to standard pressure of 1,000 mb. Ordinates are logarithms of pressure (mm. on left, mb. on right). Upper and lower abscissae are Centigrade temperatures. Form No. 1126–Aer, is a reproduction of the form used by the Lindenberg Observatory

(*d*) The fourth word will give the elevation (meters) of the first "level," the same set of words being used for heights as for temperature and humidity. The "units" place digit, in the elevation, will always be considered zero and, therefore, not indicated in the code word. The "tens" place digit will always be changed to

" even " in accordance with the following rule: If the " units " place digit is other than zero and the " tens " place digit is " odd," the latter will be increased to the next " even " figure. Example, 831 becomes 840. If the " units " place digit is zero and the " tens " place digit is " odd," the latter will be decreased to the next " even " figure. Example: 5170 becomes 5160; 4210 becomes 4200.

The " hundreds " and " tens " place digits will be indicated by the second syllable of the code word and the " thousands " place digit by the first letter of the word, the second letter always being " U." Examples:

Actual height	Coded height	Code word
87	80	UPON.
107	100	UNBUCKLE.
831	840	UPSET
1, 268	1, 260	BUDDING.
2, 278	2, 280	DUNDORE.
3, 015	3, 020	FULHAM.
4, 010	4, 000	GUY.
5, 170	5, 160	MURBISH.
6, 250	6. 240	NUDE.

(*e*) The fifth word will give the temperature and relative humidity at the first " level."

182. Thereafter will be given, alternately, a word indicating th elevation of each successive " level " and a word indicating th temperature and humidity at that " level," as explained above.

183. Following these words the message will contain the " cloud word. Clouds and cloud heights will be sent in the same way a in pilot balloon reports, instructions for which will be found in th Aerological Code, except that elevations will be given above sea level. Cloud altitudes are very important in kite reports and shoul be given whenever possible. When they are determined from angula readings made on the head kite, a deduction of 2 per cent will b made to the computed height above the surface, to allow for sag in the wire.

184. In selecting the " levels " to be telegraphed the following general rules will govern:

(*a*) Place " levels " at the base and top of all temperature inversions, except that when two or more very small inversions occur close together, only the base of the lower and top of the upper, will be sent.

(*b*) " Levels " should be so placed that a linear interpolation of the temperature, humidity and wind between them, will indicate, practically, the actual conditions; in other words, wherever a variation in the vertical gradient of any of these elements occurs. Owing to the frequent relatively small changes in humidity a tolerance of 10 per cent is permitted in this element.

(*c*) Humidity changes accompanying sudden temperature changes frequently lag on the meteorograph record, especially when the former *decreases*. In such cases proper allowance should be made for this lag. (See fig. 19.)

(*d*) A " level " should always be placed at the maximum altitude.

X. PREPARING THE RECORDS FOR FORWARDING TO WASHINGTON

185. The records are forwarded to Washington each week, where they are computed and tabulated in detail. The following preliminary steps will be performed at the station before forwarding the records:

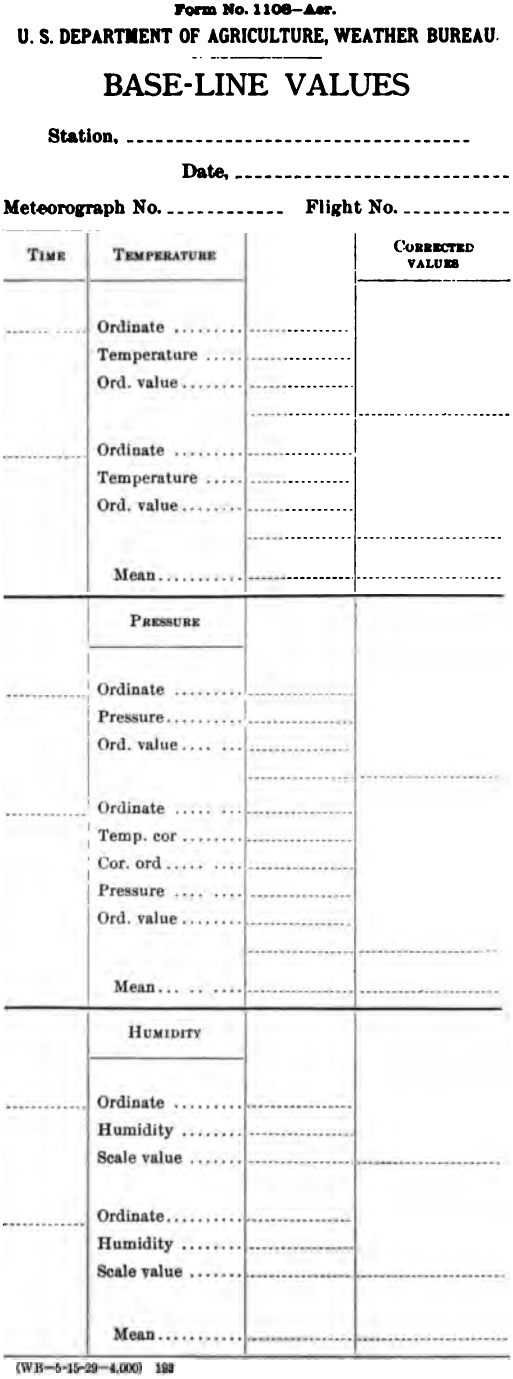
(*a*) Draw "hour lines," i. e., arcs, with a radius equal to the length of the pen arm. The exact positions of these arcs are determined by means of a special celluloid scale having equally spaced divisions corresponding to the average hour interval of all clocks, the time rate of which varies slightly for different clocks. The important point to be remembered in this connection is the necessity for the "hour lines" on the traces of the various elements to be absolutely synchronized, whereas, their position as regards actual time is of secondary importance. This is accomplished by locating the time arcs on the pressure trace as described above and marking these points on the edge of a sheet of paper. This paper is then placed over each of the other three traces and the points are thus synchronously determined since all are measured with reference to readily identifiable corresponding points on the traces, such as "pens up" or "pens down." The same method is applied to placing "levels" which are indicated by arrows pointing to dots on the traces. (See fig. 19.)

When drawing "hour lines", care must be taken to have the centers of the arcs located at the same point, i. e., the same ordinate on the record sheet as the center of rotation of the pen arms.

(*b*) Base lines will be drawn on the meteorogram and computed on Form 1108, Figure 32. This is done by drawing a light pencil line along one of the horizontal printed lines on the record sheet, choosing that line which is nearest both ends of the trace under consideration.

186. Referring to section headed Temperature, Figure 32, the times to be entered are those of "pens up," just previous to launching and of "pens up," at the end of the flight. The "ordinates," at the times referred to above, are the number of divisions (and tenths), the trace is above (entered as +), or below (entered as −) the base line. The surface temperatures at the corresponding times are entered in the spaces provided. The ordinate value is obtained by multiplying the ordinate by the temperature factor (scale value). The ordinate values are then added to or subtracted from the respective temperatures, depending on whether the ordinate is below or above the base line. The mean of these two values is taken as the value of the base line. A tolerance of 2° C. is allowed as the difference between the values for both ends as obtained above. When a greater difference occurs it is usually better to use the value obtained for one end as the base-line value, usually the beginning of the trace.

187. With reference to section headed Pressure, Figure 32, the same times are entered in the left-hand column as for Temperature. The ordinates are read in the same way. The pressures (surface) are found by interpolation between the hourly readings as entered on the data sheet (Form 1107). The ordinate values are obtained from the pressure table, which gives the corresponding pressures in millibars for various ordinates. The temperature correction is applied to the pressure ordinate at the end of the trace. The amount



Form No. 1108—Aer.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU

BASE-LINE VALUES

Station, ...

Date, ...

Meteorograph No. .... Flight No. ....

TIME	TEMPERATURE		CORRECTED VALUES
....	Ordinate	....	
	Temperature	....	
	Ord. value	....	
		....	....
....	Ordinate	....	
	Temperature	....	
	Ord. value	....	
		....	....
	Mean	....	....
	PRESSURE		
....	Ordinate	....	
	Pressure	....	
	Ord. value	....	
		....	....
....	Ordinate	....	
	Temp. cor	....	
	Cor. ord	....	
	Pressure	....	
	Ord. value	....	
		....	....
	Mean	....	....
	HUMIDITY		
....	Ordinate	....	
	Humidity	....	
	Scale value	....	....
....	Ordinate	....	
	Humidity	....	
	Scale value	....	....
	Mean	....	....

(WB—5-15-29—4,000) 188

FIGURE 32.—Form used for computing base lines

of this correction
termined by divid
"temperature cor
factor for the p
element by the
in surface tempe
between the time
cated in the lef
column of the P
section of Form 1

188. Since the p
ordinates carry a
braic sign denoti
position with re
to the base line, t
plication of the te
ture correction m
confusing unl
steps are clearly
stood. The fol
examples will i
the method to b
on Form 1108

(*a*) Pressure o
positive (with re
to base line); s
temperature *rose*
flight; temperatu
rection on pressu
ment (inversel
plied)[8] is enter
positive and add
pressure ordinate
tain corrected p
ordinate.

(*b*) Pressure o
negative; surface
perature *rose*
flight; temperatu
rection on pressu
ment (inversel
plied) is entered a
tive and added
braically) to p
ordinate to obtai
rected pressure or

(*c*) Pressure o
positive; surface
perature *fell*
flight; temperatu
rection on pressu
ment (inversel

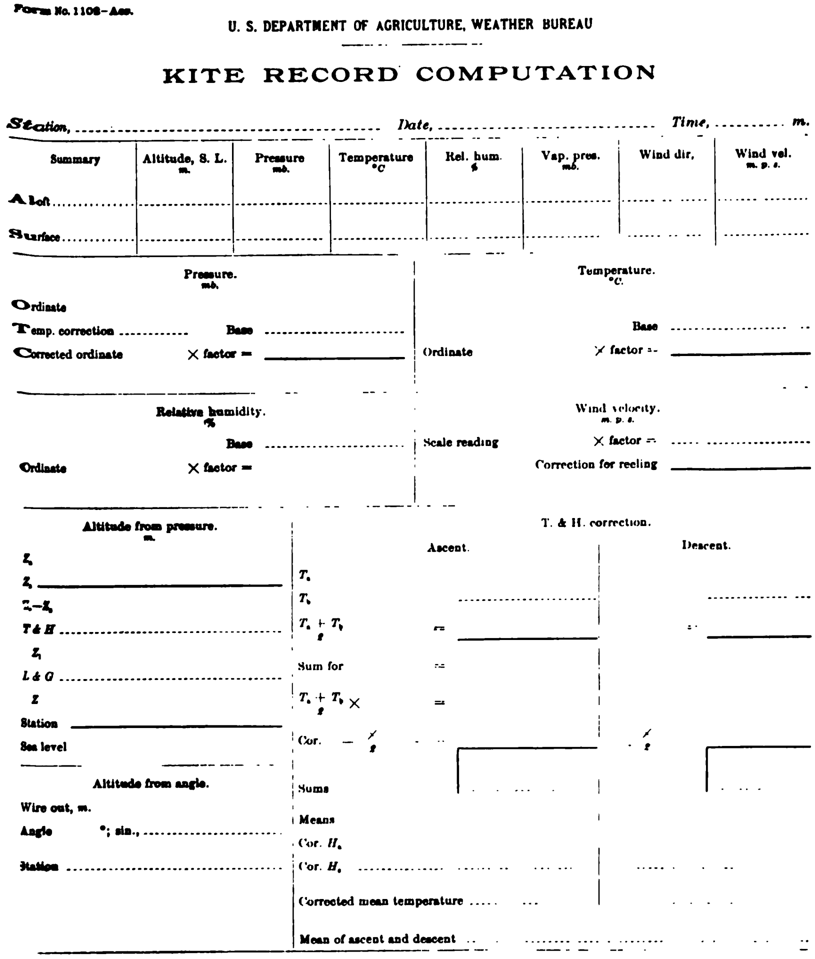
---

[8] By "inversely applied" is meant the correction made when a rise in tempera
the effect of a fall in pressure and vice versa. "Directly applied" refers to th
rections made when a rise in temperature has the effect of a rise in pressure
versa. (See Sec. VII, pars. 87 and 88.

plied) is entered as *negative* and added (algebraically) to pressure ordinate to obtain corrected pressure ordinate.

(*d*) Pressure ordinate *negative;* surface temperature *fell* during flight; temperature correction on pressure element (inversely applied) is entered as *negative* and added (algebraically) to pressure ordinate to obtain corrected pressure ordinate.

(*e*) When the temperature correction on the pressure element is *directly* applied,[8] its algebraic sign is reversed in each of the above cases and the value added (algebraically) to the pressure ordinate to obtain the corrected pressure ordinate.



Form No. 1108–Aer.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU

KITE RECORD COMPUTATION

Station, ... Date, ... Time, ... m.

Summary	Altitude, S. L. m.	Pressure mb.	Temperature °C	Rel. hum. %	Vap. pres. mb.	Wind dir.	Wind vel. m. p. s.
Aloft							
Surface							

Pressure. mb.

Ordinate

Temp. correction .... Base ....

Corrected ordinate × factor = ...

Temperature. °C.

Base ....

Ordinate × factor = ...

Relative humidity. %

Base ....

Ordinate × factor =

Wind velocity. m. p. s.

Scale reading × factor = ...

Correction for reeling ....

Altitude from pressure. m.

Z_a

Z_b

$Z_a - Z_b$

T & H ....

Z_1

L & G ....

Z

Station

Sea level

Altitude from angle.

Wire out, m.

Angle °; sin., ...

Station ....

T. & H. correction.

Ascent. Descent.

T_a

T_b

$\frac{T_a + T_b}{2}$ =

Sum for =

$\frac{T_a + T_b}{2} \times$ =

Cor. $-\frac{/}{2}$ $\frac{/}{2}$

Sums

Means

Cor. H_a

Cor. H_d

Corrected mean temperature ....

Mean of ascent and descent ....

(WB—8-7-29—20,000)

FIGURE 33.—Form used for computing kite records

189. The pressure ordinate values obtained for both ends of the base line are added algebraically to the surface pressures and the mean of the two values is taken as the base-line value. A tolerance

of 5 millibars is allowed as the difference between the values for both ends as obtained above.

190. With reference to the section headed Humidity, Figure 32, the same times are entered in the left-hand column as for temperature and pressure. The ordinates are read in the same way. The surface relative humidity for the two times entered is placed in the space provided. The value of each end of the base line is then found by placing the zero point of the "standard" humidity scale against the value of the surface humidity on the "special" scale. If the ordinate value is positive, the value for that end of the base line is found by reading down on the "standard" scale the same number of ordinates and reading off the corresponding humidity on the "special" scale. A tolerance of 10 per cent is allowed between the end values of the humidity base line.

191. Before forwarding the records to Washington they should be carefully examined by an experienced member of the station force to see that all details have been properly attended to.

XI. DETAILED COMPUTATION OF KITE RECORDS

192. The fundamental basis for determining heights by the barometer is the original formula of Laplace, amplified into the following form:

$$(1)\qquad Z=K(1+\alpha\theta)\left(\frac{1}{1-0.378^{e}}\right)\left(1+\frac{g-g_l}{g}\right)\left(1+\frac{h+h_o}{R}\right)\log\frac{p_o}{p},$$

or where g_l, the value of local gravity is unknown,

$$(2)\quad Z=K(1+\alpha\theta)\left(\frac{1}{1-0.378\frac{e}{b}}\right)(1+k\cos 2\phi-k'\cos^2 2\phi+C)\left(1+\frac{h+h_o}{R}\right)$$

$$\log\frac{p_o}{p}\text{ in which}$$

h = Height of the upper station.
h_o = Height of the lower station.
$Z = \mathrm{h}-\mathrm{h}_o$.
p = Atmospheric pressure at the upper station.
p_o = Atmospheric pressure at the lower station.
R = Mean radius of the earth.
θ = Mean temperature of the air column between the altitudes h and h_o.
e = Mean pressure of aqueous vapor in the air column.
b = Mean barometric pressure of the air column.
ϕ = Latitude of the stations.
K = Barometric constant.
α = Coefficient of the expansion of air.
k and k' = Constants depending on the figure of the earth.
C = Constant = the ratio $\frac{g_{45^\circ}-g}{g}$.
g = Standard value of gravity = 980.665 dynes.
g_l = Local value of gravity.

A more detailed discussion of this formula is published in the Smithsonian Meteorological Tables.

193. Form 1102 (fig. 33) is used for computing kite records in detail. One of these forms is used for each level. They are largely

self-explanatory, but some explanation will be made with particular reference to the lower half of the sheet.

194. The values Z_a and Z_s are obtained from the table shown in Figure 34, using the pressures at the surface and at the first " level "

DETERMINATION OF HEIGHTS BY THE BAROMETER.

(Values of 18400 log $\frac{1013.3}{B}$; adapted from Table 25, S. I. Meteorological Tables.)

Pressure (mb.)	0	1	2	3	4	5	6	7	8	9	P. P.		
	METERS.												
500	5645	5629	5613	5597	5581	5565	5549	5533	5518	5502	......	16	15
510.	5486	5471	5455	5439	5424	5408	5393	5377	5362	5346	0. 1	2	2
520	5331	5316	5300	5285	5270	5255	5239	5224	5209	5194	.2	3	3
530	5179	5164	5149	5134	5119	5104	5089	5074	5059	5044	.3	5	4
540	5030	5015	5000	4985	4971	4956	4941	4927	4912	4898	.4	6	6
550	4883	4868	4854	4839	4825	4811	4796	4782	4768	4753	.5	8	8
560	4739	4725	4710	4696	4682	4668	4654	4640	4626	4612	.6	10	9
570	4598	4583	4569	4556	4542	4528	4514	4500	4486	4472	.7	11	10
580	4459	4445	4431	4417	4404	4390	4376	4363	4349	4335	.8	13	12
590	4322	4308	4295	4281	4268	4254	4241	4228	4214	4201	.9	14	14
600	4188	4174	4161	4148	4134	4121	4108	4095	4082	4069	......	14	13
610	4056	4042	4029	4016	4003	3990	3977	3964	3951	3939	0. 1	1	1
620	3926	3913	3900	3887	3874	3861	3849	3836	3823	3810	.2	3	3
630	3798	3785	3772	3760	3747	3735	3722	3709	3697	3684	.3	4	4
640	3672	3659	3647	3635	3622	3610	3597	3585	3573	3560	.4	6	5
650	3548	3536	3523	3511	3499	3487	3475	3462	3450	3438	.5	7	6
660	3426	3414	3402	3390	3378	3366	3354	3342	3330	3318	.6	8	8
670	3306	3294	3282	3270	3258	3246	3235	3223	3211	3199	.7	10	9
680	3187	3176	3164	3152	3141	3129	3117	3106	3094	3082	.8	11	10
690	3071	3059	3048	3036	3025	3013	3002	2990	2979	2967	.9	13	12
700	2956	2944	2933	2922	2910	2899	2888	2876	2865	2854	......	12	11
710	2842	2831	2820	2809	2798	2786	2775	2764	2753	2742	0. 1	1	1
720	2731	2720	2708	2697	2686	2675	2664	2653	2642	2631	.2	2	2
730	2621	2609	2599	2588	2577	2566	2555	2544	2533	2523	.3	4	3
740	2512	2501	2490	2479	2469	2458	2447	2437	2426	2415	.4	5	4
750	2405	2394	2383	2373	2362	2351	2341	2330	2320	2309	.5	6	6
760	2299	2288	2278	2267	2257	2246	2236	2225	2215	2205	.6	7	7
770	2194	2184	2173	2163	2153	2142	2132	2122	2112	2101	.7	8	8
780	2091	2081	2071	2060	2050	2040	2030	2020	2009	1999	.8	10	9
790	1989	1979	1969	1959	1949	1939	1929	1919	1909	1899	.9	11	10
800	1889	1879	1869	1859	1849	1839	1829	1819	1809	1799	......	9	8
810	1789	1780	1770	1760	1750	1740	1731	1721	1711	1701	0. 1	1	1
820	1692	1682	1672	1662	1653	1643	1633	1623	1614	1604	.2	2	2
830	1595	1585	1575	1566	1556	1547	1537	1527	1518	1508	.3	3	2
840	1499	1489	1480	1470	1461	1451	1442	1433	1423	1414	.4	4	3
850	1404	1395	1386	1376	1367	1357	1348	1339	1329	1320	.5	4	4
860	1311	1302	1292	1283	1274	1264	1255	1246	1237	1228	.6	5	5
870	1218	1209	1200	1191	1182	1173	1164	1154	1145	1136	.7	6	6
880	1127	1118	1109	1100	1091	1082	1073	1064	1055	1046	.8	7	6
890	1037	1028	1019	1010	1001	992	983	974	965	956	.9	8	7
900	948	939	930	921	912	903	894	886	877	868	......	7	----
910	859	850	842	833	824	815	807	798	789	781	0. 1	1	
920	772	763	755	746	737	729	720	711	703	694	.2	1	
930	686	677	668	660	651	643	634	626	617	608	.3	2	
940	600	592	583	575	566	558	549	541	532	524	.4	3	
950	516	507	499	490	482	474	465	457	448	440	.5	4	
960	432	424	415	407	399	390	382	374	365	357	.6	4	
970	349	341	332	324	316	308	300	292	283	275	.7	5	
980	267	259	251	243	234	226	218	210	202	194	.8	6	
990	186	178	170	162	154	146	138	130	122	114	.9	6	
1000	106	98	90	82	74	66	58	50	42	34			
1010	26	18	10	2	-6	-13	-21	-29	-37	-45			
1020	-53	-61	-68	-76	-84	-92	-100	-107	-115	-123			
1030	-131	-138	-146	-154	-162	-169	-177	-185	-192	-200			
1040	-208	-215	-223	-231	-238	-246	-254	-261	-269	-277			

Figure 34.—Heights corresponding to various barometric pressures, based on a mean temperature of the intervening air column of 0° C. (For pressures below 500 mb., see Smithsonian Meteorological Tables)

as arguments. Their difference $(Z_a - Z_s)$ which is the approximate elevation, is then multiplied by the T and H (temperature and humidity) correction factor. The latter is obtained from the table shown in Figure 35, using the mean temperature of the air column, θ, as the argument. This product is then added to $Z_a - Z_s$ when the mean temperature is above 0°C., and subtracted when below 0°C.

195. The L and G (latitude and gravity) correction is obtained from Tables 62 and 63. Smithsonian Meterological Tables, 1918, and is added to the height (Z). To this is added the station elevation, since, in kite work, all elevations are referred to sea level.

TEMPERATURE CORRECTION FACTOR. (A.)

(Multiply values of $Z_a - Z_s$ by a; add correction when mean temperature is above 0° C; subtract when below 0° C.)

Mean Temp. °C.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
	a	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*
0	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.003
1	.004	.004	.004	.005	.005	.006	.006	.006	.007	.007
2	.007	.008	.008	.008	.009	.009	.010	.010	.010	.011
3	.011	.011	.012	.012	.012	.013	.013	.014	.014	.014
4	.015	.015	.015	.016	.016	.017	.017	.017	.018	.018
5	.018	.019	.019	.019	.020	.020	.021	.021	.021	.022
6	.022	.022	.023	.023	.023	.024	.024	.025	.025	.025
7	.026	.026	.026	.027	.027	.028	.028	.028	.029	.029
8	.029	.030	.030	.030	.031	.031	.032	.032	.032	.033
9	.033	.033	.034	.034	.034	.035	.035	.036	.036	.036
10	.037	.037	.037	.038	.038	.039	.039	.039	.040	.040
11	.040	.041	.041	.041	.042	.042	.043	.043	.043	.044
12	.044	.044	.045	.045	.046	.046	.046	.047	.047	.047
13	.048	.048	.048	.049	.049	.050	.050	.050	.051	.051
14	.051	.052	.052	.052	.053	.053	.054	.054	.054	.055
15	.055	.055	.056	.056	.057	.057	.057	.058	.058	.058
16	.059	.059	.059	.060	.060	.061	.061	.061	.062	.062
17	.062	.063	.063	.063	.064	.064	.065	.065	.065	.066
18	.066	.066	.067	.067	.068	.068	.068	.069	.069	.069
19	.070	.070	.070	.071	.071	.072	.072	.072	.073	.073
20	.073	.074	.074	.075	.075	.075	.076	.076	.076	.077
21	.077	.077	.078	.078	.079	.079	.079	.080	.080	.080
22	.081	.081	.081	.082	.082	.083	.083	.083	.084	.084
23	.084	.085	.085	.086	.086	.086	.087	.087	.087	.088
24	.088	.088	.089	.089	.090	.090	.090	.091	.091	.091
25	.092	.092	.092	.093	.093	.094	.094	.094	.095	.095
26	.095	.096	.096	.097	.097	.097	.098	.098	.098	.099
27	.099	.099	.100	.100	.101	.101	.101	.102	.102	.102
28	.103	.103	.103	.104	.104	.105	.105	.105	.106	.106
29	.106	.107	.107	.108	.108	.108	.109	.109	.109	.110
30	.110	.110	.111	.111	.112	.112	.112	.113	.113	.113
31	.114	.114	.115	.115	.115	.116	.116	.116	.117	.117
32	.117	.118	.118	.119	.119	.119	.120	.120	.120	.121
33	.121	.121	.122	.122	.123	.123	.123	.124	.124	.124
34	.125	.125	.126	.126	.126	.127	.127	.127	.128	.128
35	.128	.129	.129	.130	.130	.130	.131	.131	.131	.132
36	.132	.132	.133	.133	.134	.134	.134	.135	.135	.135
37	.136	.136	.137	.137	.137	.138	.138	.138	.139	.139
38	.139	.140	.140	.141	.141	.141	.142	.142	.142	.143
39	.143	.143	.144	.144	.145	.145	.145	.146	.146	.146

FIGURE 35.—Table of temperature correction factors for use in obtaining heights from barametric pressures

196. The above computations refer only to the first computed level above the surface, on the ascent and descent, respectively. In these cases, θ is simply equal to one-half the sum of the temperature aloft and that at the surface, viz, $\left(\frac{T_a + T_b}{2}\right)$. This method of obtain-

g θ can be used only when the lapse rate is uniform throughout e stratum. However, since the " levels " are placed at points where e lapse rate changes, it is obvious that the value of θ between e surface and " levels " above the first (and last) can not be so nply obtained. This is done then, by averaging the mean temper- ıres of successive strata according to their thicknesses, the latter ng considered only to the nearest hundred meters. For example, the first level is at a height h, the mean temperature of the air ımn is $\frac{T_s+T_a}{2}$, as previously stated. In the case of the next her " level " at a height h', the mean temperature of the inter- ing air column is obtained from the following:

$$\frac{h\left(\frac{T_s+T_a}{2}\right)+\left(h'-h\right)\left(\frac{T_a+T_{a'}}{2}\right)}{h'} \tag{1}$$

97. Since the interval between launching and landing the instru- ıt kite is usually several hours, it is obvious that the suface tem- ature, and that for a certain distance above, will frequently e changed appreciably. Therefore, it is necessary to introduce urther correction for this change. The height to which this nge extends depends largely upon the diathermance of the lower ıta, and upon the extent of convectional activity. To deter- ıe this height the temperatures observed during the ascent and cent, respectively, are plotted against their corresponding heights $\text{ı}-Z_s$). (See Fig. 36.) The temperature at the first " level " of ascent is plotted at the corresponding height and also the surface ıperature at the time of the first " level." These two points are nected by a straight line and the same procedure followed for temperatures at the lowest " level " of the descent and the corre- nding surface temperature. The temperatures at successively her " levels " are then plotted against their corresponding heights, connected by straight lines until the lines representing the ascent descent converge to within 1° C. of each other. The height at ch this convergance occurs is accepted as the height to which the face warming (or cooling) extends. This height, in the case of ure 36, is 500 m.

98. The amount of this correction is obtained from the following, , $h_c\left(\frac{T_s-T_{s'}}{2}\right)$, which is introduced in equation (1), so that the er becomes,

$$\frac{h\left(\frac{T_s+T_a}{2}\right)+\left(h'-h\right)\left(\frac{T_a+T_{a'}}{2}\right)+h_c\left(\frac{T_s-T_{s'}}{2}\right)}{h'} \tag{2}$$

he factor just added, viz., h_c, represents the height (to the nearest ıdred meters) at which the difference between the free-air tem- atures of the ascent and descent is 1° C., or less; T_s and $T_{s'}$ are surface temperatures corresponding to the T_a and $T_{a'}$ respectively.

199. In computing any "level" below the height h_c, the elevation of the "level" itself is substituted as the value for h_c. For "levels" *higher* than h_c, the value of the latter is used. h_c is considered as zero whenever the difference between the surface temperatures at the times of the first, i. e., lowest "levels" of the ascent and descent, respectively, is 1° C. or less.

200. When, for any reason, only the ascent or descent is computed, h_c is given a value of 5, unless the temperature difference referred to in the preceding paragraph is 1° C. or less, at which times, h_c is considered as zero.

201. To the mean temperature of the air column (θ) obtained as previously explained, a correction for humidity must be added. The latter is obtained from the Table shown in Figure 37, using the barometric and vapor pressures as arguments. This correction is indicated in terms of temperature and is always additive.

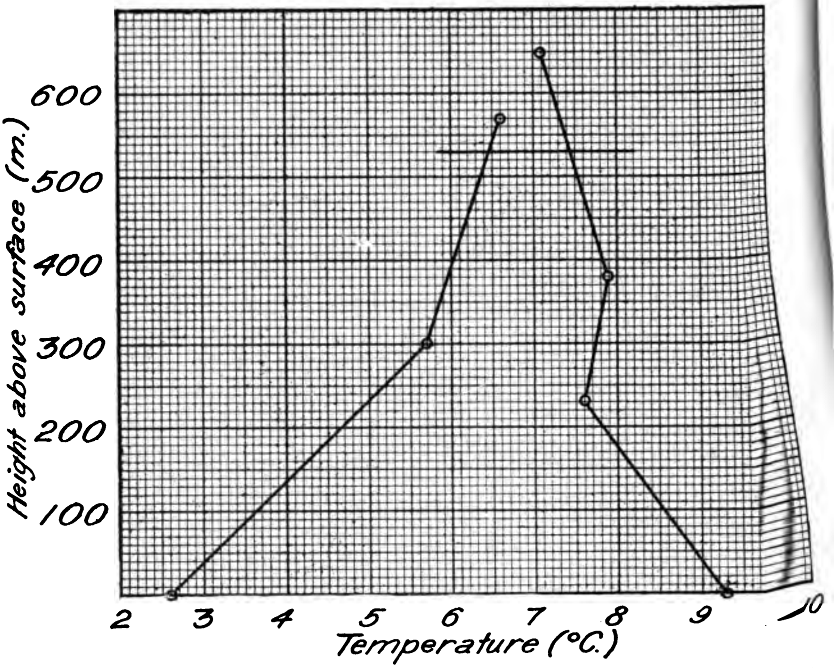


FIGURE 36.—Temperature graph for determining limiting height of temperature change during kite flight

202. The corrected value of θ is determined as explained above, beginning with the first "level" of the ascent and continuing upward to the highest "level"; then again working upward, through the descent, to and including the highest "level." The mean of the values of θ so obtained for the ascent and descent, respectively, is then used for computing the elevation of the highest "level."

HUMIDITY CORRECTION—ADD TO MEAN TEMPERATURE.

VAPOR PRESSURE (MB.)													
0.5	1	2	3	4	5	6	7	8	9	10	20	30	40
°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	1.0	1.5	2.0
.0	.1	.1	.2	.2	.3	.3	.4	.4	.5	.5	1.0	1.5	2.0
.0	.1	.1	.2	.2	.3	.3	.4	.4	.5	.5	1.0	1.5	2.1
.0	.1	.1	.2	.2	.3	.3	.4	.4	.5	.5	1.1	1.6	2.1
.0	.1	.1	.2	.2	.3	.3	.4	.4	.5	.5	1.1	1.6	2.1
.0	.1	.1	.2	.2	.3	.3	.4	.4	.5	.5	1.1	1.6	2.2
.0	.1	.1	.2	.2	.3	.3	.4	.4	.5	.6	1.1	1.7	2.2
.0	.1	.1	.2	.2	.3	.3	.4	.5	.5	.6	1.1	1.7	2.3
.0	.1	.1	.2	.2	.3	.4	.4	.5	.5	.6	1.2	1.8	2.3
.0	.1	.1	.2	.2	.3	.4	.4	.5	.5	.6	1.2	1.8	2.4
.0	.1	.1	.2	.2	.3	.4	.4	.5	.6	.6	1.2	1.8	
.0	.1	.1	.2	.3	.3	.4	.4	.5	.6	.6	1.3	1.9	
.0	.1	.1	.2	.3	.3	.4	.5	.5	.6	.6	1.3	1.9	
.0	.1	.1	.2	.3	.3	.4	.5	.5	.6	.7	1.3	2.0	
.0	.1	.1	.2	.3	.3	.4	.5	.5	.6	.7	1.4		
.0	.1	.1	.2	.3	.3	.4	.5	.6	.6	.7	1.4		
.0	.1	.1	.2	.3	.4	.4	.5	.6	.6	.7	1.4		
.0	.1	.1	.2	.3	.4	.4	.5	.6	.7	.7	1.5		
.0	.1	.2	.2	.3	.4	.5	.5	.6	.7	.8			
.0	.1	.2	.2	.3	.4	.5	.5	.6	.7	.8			
.0	.1	.2	.2	.3	.4	.5	.6	.6	.7	.8			
.0	.1	.2	.2	.3	.4	.5	.6	.7	.7				
.0	.1	.2	.3	.3	.4	.5	.6	.7	.8				
.0	.1	.2	.3	.4	.4	.5	.6	.7	.8				
.0	.1	.2	.3	.4	.5	.6	.6	.7					
.0	.1	.2	.3	.4	.5	.6	.7	.8					
.0	.1	.2	.3	.4	.5	.6	.7	.8					
.1	.1	.2	.3	.4	.5	.6	.7						
.1	.1	.2	.3	.4	.5	.6	.8						
.1	.1	.2	.3	.4	.6	.7	.8						
.1	.1	.2	.4	.5	.6	.7							
.1	.1	.2	.4	.5	.6	.7							
.1	.1	.3	.4	.5	.6	.8							
.1	.1	.3	.4	.5	.7								
.1	.1	.3	.4	.6	.7								
.1	.2	.3	.5	.6	.8								
.1	.2	.3	.5	.6									
.1	.2	.3	.5	.7									
.1	.2	.4	.6	.7									
.1	.2	.4	.6										
.1	.2	.4	.6										
.1	.2	.5	.7										
.1	.3	.5											
.1	.3	.6											
.2	.3	.6											
.2	.4												
.2	.4												
.3	.5												
.3													
.4													
.6													
1.3													
2.6													

JRE 37.—Humidity correction table for use in obtaining heights from barometric pressures

203. The Tables shown in Figures 38 and 39 give the saturatio vapor pressures for various temperatures. These values multiplie by the relative humidity give the actual vapor pressure.

PRESSURE OF AQUEOUS VAPOR.

Temp. °C.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
	MILLIBARS.									
0	6.11	6.15	6.20	6.24	6.29	6.33	6.38	6.42	6.47	6.52
1	6.56	6.61	6.66	6.71	6.76	6.81	6.86	6.90	6.95	7.00
2	7.05	7.10	7.16	7.21	7.26	7.31	7.36	7.42	7.47	7.52
3	7.58	7.63	7.68	7.74	7.79	7.85	7.90	7.96	8.02	8.07
4	8.13	8.19	8.25	8.30	8.36	8.42	8.48	8.54	8.60	8.66
5	8.72	8.78	8.84	8.91	8.97	9.03	9.09	9.16	9.22	9.28
6	9.35	9.41	9.48	9.54	9.61	9.68	9.74	9.81	9.88	9.95
7	10.02	10.09	10.16	10.22	10.30	10.37	10.44	10.51	10.58	10.65
8	10.73	10.80	10.87	10.95	11.02	11.10	11.17	11.25	11.32	11.40
9	11.48	11.56	11.64	11.71	11.79	11.87	11.95	12.03	12.12	12.20
10	12.28	12.36	12.44	12.53	12.61	12.70	12.78	12.87	12.95	13.0[illegible]
11	13.13	13.21	13.30	13.39	13.48	13.57	13.66	13.75	13.84	13.9[illegible]
12	14.03	14.12	14.21	14.31	14.40	14.50	14.59	14.69	14.78	14.[illegible]
13	14 98	15.08	15.18	15.28	15.38	15.48	15.58	15.68	15.78	15.[illegible]
14	15.99	16.09	16.20	16.30	16.41	16.51	16.62	16.73	16.84	16.[illegible]
15	17.06	17.17	17.28	17.39	17.50	17.61	17.73	17.84	17.96	18.[illegible]
16	18.19	18.30	18.42	18.54	18.66	18.78	18.90	19.02	19.14	19.[illegible]
17	19.38	19.51	19.63	19.76	19.88	20.01	20.13	20.26	20.39	20.[illegible]
18	20.65	20.78	20.91	21.04	21.17	21.31	21.44	21.58	21.71	21.[illegible]
19	21.98	22.12	22.26	22.40	22.54	22.68	22.82	22.96	23.11	23.[illegible]
20	23.40	23.54	23.69	23.83	23.98	24.13	24.28	24.43	24.58	24.[illegible]3
21	24.88	25.04	25.19	25.35	25.50	25.66	25.82	25.98	26.14	26.30
22	26.46	26.62	26.78	26.94	27.11	27.27	27.44	27.61	27.78	27.94
23	28.11	28.28	28.46	28.63	28.80	28.98	29.15	29.33	29.51	29.68
24	29.86	30.04	30.22	30.40	30.59	30.77	30.96	31.14	31.33	31.51
25	31.70	31.89	32.08	32.28	32.47	32.66	32.86	33.05	33.25	33.45
26	33.64	33.84	34.04	34.25	34.45	34.65	34.86	35.06	35.27	35.48
27	35.69	35.90	36.11	36.32	36.53	36.75	36.96	37.18	37.40	37.62
28	37.84	38.06	38.28	38.50	38.73	38.95	39.18	39.41	39.64	39.87
29	40.10	40.33	40.56	40.80	41.04	41.27	41.51	41.75	41.99	42.23
30	42.48	42.72	42.97	43.21	43.46	43.71	43.96	44.21	44.47	44.72
31	44.98	45.23	45.49	45.75	46.01	46.27	46.54	46.80	47.07	47.33
32	47.60	47.87	48.14	48.42	48.69	48.97	49.24	49.52	49.80	50.08
33	50.36	50.65	50.93	51.22	51.50	51.79	52.08	52.37	52.67	52.96
34	53.26	53.56	53.85	54.15	54.46	54.76	55.06	55.37	55.68	55.99
35	56.30	56.61	56.92	57.24	57.56	57.87	58.19	58.51	58.84	59.16
36	59.49	59.81	60.14	60.47	60.81	61.14	61.47	61.81	62.15	62.49
37	62.83	63.17	63.52	63.86	64.21	64.56	64.91	65.27	65.62	65.98
38	66.34	66.69	67.06	67.42	67.78	68.15	68.52	68.89	69.26	69.63
39	70.01	70.38	70.76	71.14	71.53	71.91	72.30	72.68	73.07	73.46
40	73.86	74.25	74.65	75.04	75.44	75.85	76.25	76.66	77.06	77.47
41	77.88	78.30	78.71	79.13	79.55	79.97	80.39	80.81	81.24	81.67
42	82.10	82.53	82.97	83.40	83.84	84.28	84.72	85.17	85.61	86.06
43	86.51	86.96	87.42	87.87	88.33	88.79	89.26	89.72	90.19	90.66
44	91.33	91.60	92.07	92.55	93.03	93.51	93.99	94.48	94.97	95.46

FIGURE 38.—Saturation vapor pressure table for temperatures from 0° to 44° C.

PRESSURE OF AQUEOUS VAPOR.

Temp. °C.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
	MILLIBARS									
-34	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.23	0.23	0.23
-33	.28	.28	.27	.27	.27	.26	.26	.26	.26	.25
-32	.31	.31	.30	.30	.30	.30	.29	.29	.28	.28
-31	.34	.34	.34	.34	.33	.33	.32	.32	.32	.31
-30	.38	.38	.38	.37	.37	.36	.36	.36	.35	.35
-29	.43	.42	.42	.41	.41	.40	.40	.40	.39	.39
-28	.47	.47	.46	.46	.45	.45	.44	.44	.44	.43
-27	.52	.52	.51	.51	.50	.50	.49	.49	.48	.48
-26	.58	.57	.57	.56	.56	.55	.54	.54	.53	.53
-25	.64	.63	.63	.62	.62	.61	.60	.60	.59	.58
-24	.71	.70	.69	.69	.68	.67	.67	.66	.65	.65
-23	.78	.77	.77	.76	.75	.74	.74	.73	.72	.71
-22	.86	.85	.84	.84	.83	.82	.81	.80	.80	.79
-21	.95	.94	.93	.92	.91	.90	.89	.89	.88	.87
-20	1.04	1.03	1.02	1.01	1.00	1.00	.99	.98	.97	.96
-19	1.15	1.14	1.13	1.12	1.11	1.10	1.09	1.07	1.06	1.05
-18	1.26	1.25	1.24	1.23	1.22	1.20	1.19	1.18	1.17	1.16
-17	1.39	1.37	1.36	1.35	1.34	1.32	1.31	1.30	1.29	1.27
-16	1.52	1.51	1.49	1.48	1.47	1.45	1.44	1.43	1.41	1.40
-15	1.67	1.65	1.64	1.62	1.61	1.59	1.58	1.57	1.55	1.54
-14	1.83	1.81	1.80	1.78	1.76	1.75	1.73	1.72	1.70	1.69
-13	2.00	1.99	1.97	1.95	1.93	1.92	1.90	1.88	1.86	1.85
-12	2.19	2.17	2.15	2.13	2.12	2.10	2.08	2.06	2.04	2.02
-11	2.40	2.38	2.35	2.33	2.31	2.29	2.27	2.25	2.23	2.21
-10	2.62	2.60	2.57	2.55	2.53	2.51	2.48	2.46	2.44	2.42
- 9	2.86	2.83	2.81	2.78	2.76	2.74	2.71	2.69	2.67	2.64
- 8	3.12	3.09	3.07	3.04	3.01	2.99	2.96	2.93	2.91	2.88
- 7	3.40	3.37	3.34	3.31	3.29	3.26	3.23	3.20	3.17	3.15
- 6	3.70	3.67	3.64	3.61	3.58	3.55	3.52	3.49	3.46	3.43
- 5	4.03	4.00	3.97	3.93	3.90	3.87	3.83	3.80	3.77	3.74
- 4	4.39	4.35	4.31	4.28	4.24	4.21	4.17	4.14	4.10	4.07
- 3	4.77	4.73	4.69	4.65	4.61	4.58	4.54	4.50	4.46	4.42
- 2	5.18	5.14	5.10	5.06	5.01	4.97	4.93	4.89	4.85	4.81
- 1	5.63	5.58	5.53	5.49	5.44	5.40	5.36	5.31	5.27	5.23
0	6.11	6.06	6.01	5.96	5.91	5.86	5.81	5.77	5.72	5.67

FIGURE 39.—Saturation vapor pressure table for temperatures from 0° to −34° C.

204. The Table shown in Figure 40 gives the "reeling" correction, which is added to the indicated wind velocity when the kite is being reeled out and subtracted when reeled in.

205. As an approximate check on the computed altitude of the instrument kite, its elevation angle is observed by means of a theodolite at frequent intervals during the flight. The height is then determined trigonometrically from the expression $h=l \sin \phi$, where h the vertical height, l, the length of wire out (meters) and, ϕ, t elevation angle. The result thus obtained should be reduced about 2 per cent to allow for sag in the wire.

Wind directions are obtained by eye observation on the kite. When the latter are above a cloud layer the direction is estimated.

CORRECTIONS FOR WIND VELOCITY.

IN METERS PER SECOND.

REELING OUT+. REELING IN−.

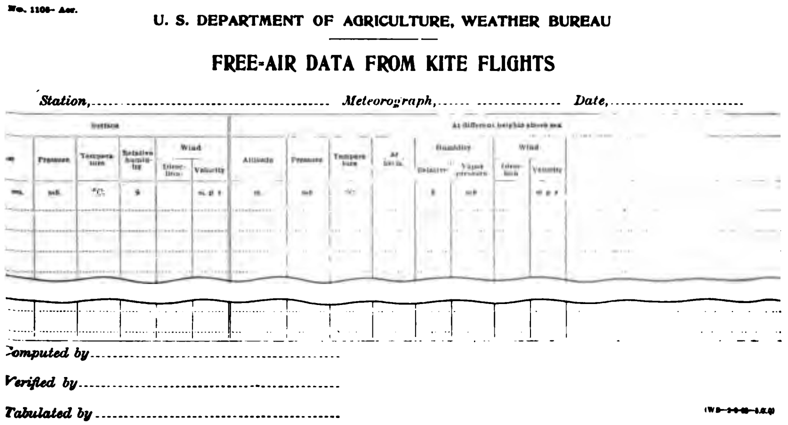
TIME AND DISTANCE BETWEEN OBSERVATIONS.

Minutes.	m. 500	m. 600	m. 700	m. 800	m. 900	m. 1,000	m. 1,100	m. 1,200	m. 1,300	m. 1,400	m. 1,500	m. 1,600	m. 1,700	m. 1,800	m. 1,900	m. 2,000
3	2.8	3.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
4	2.1	2.5	2.9	3.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
5	1.7	2.0	2.3	2.7	3.0	3.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
6	1.4	1.7	2.0	2.2	2.5	2.8	3.0	3.3	-----	-----	-----	-----	-----	-----	-----	-----
7	1.2	1.4	1.7	1.9	2.2	2.4	2.6	2.8	3.1	3.3	-----	-----	-----	-----	-----	-----
8	1.0	1.2	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	-----	-----	-----	-----
9	0.9	1.1	1.3	1.5	1.7	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.3	-----	-----
10	0.8	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.8	3.0	3.2	3.3
11	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.0
12	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.8
13	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.0	2.2	2.3	2.4	2.6
14	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.0	2.2	2.3	2.4
15	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.0	2.1	2.2
16	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1
17	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
18	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.8
19	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
20	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7
21	-----	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.6
22	-----	-----	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.5
23	-----	-----	-----	0.6	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.5
24	-----	-----	-----	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4
25	-----	-----	-----	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.3	1.3
26	-----	-----	-----	-----	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
27	-----	-----	-----	-----	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.2	1.2
28	-----	-----	-----	-----	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.0	1.1	1.2
29	-----	-----	-----	-----	-----	0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.2
30	-----	-----	-----	-----	-----	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.0	1.1
31	-----	-----	-----	-----	-----	0.5	0.6	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1
32	-----	-----	-----	-----	-----	-----	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0
33	-----	-----	-----	-----	-----	-----	0.6	0.6	0.6	0.7	0.8	0.8	0.8	0.9	1.0	1.0
34	-----	-----	-----	-----	-----	-----	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0
35	-----	-----	-----	-----	-----	-----	-----	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	1.0
36	-----	-----	-----	-----	-----	-----	-----	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9
37	-----	-----	-----	-----	-----	-----	-----	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9
38	-----	-----	-----	-----	-----	-----	-----	-----	0.6	0.6	0.6	0.7	0.8	0.8	0.8	0.8
39	-----	-----	-----	-----	-----	-----	-----	-----	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.
40	-----	-----	-----	-----	-----	-----	-----	-----	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.

FIGURE 40.—Reeling correction table for use in determining wind velocity

07. The computed data are tabulated on Form 1105 (fig. 41), the a for the standard levels, i. e., 500, 1,000, 1,500 meters, etc., being ained by linear interpolations. The barometric pressure, however, ce it does not change linearly with height, is plotted against the ght, and the points connected by a curve from which the pressures the standard levels are obtained. The vapor pressures for the ndard levels are obtained by multiplying the saturation vapor essures (figs. 38 and 39) for the given temperatures by the corresding relative humidities.

08. The column headed $\frac{\Delta t}{100\text{m.}}$ indicates the temperature lapse e and is expressed in ° C. per 100 meters. It is found by dividing temperature difference by the altitude difference. Lapse rates



No. 1105—Aer.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU

FREE-AIR DATA FROM KITE FLIGHTS

Station, ... Meteorograph, ... Date, ...

Station						At different heights above sea								
	Pressure	Temperature	Relative humidity	Wind		Altitude	Pressure	Temperature	$\frac{\Delta t}{100\text{m.}}$	Humidity		Wind		
				Direction	Velocity					Relative	Vapor pressure	Direction	Velocity	
	mb.	°C.	%		m. p. s.	m.	mb.	°C.		%	mb.		m. p. s.	

Computed by ....

Verified by ....

Tabulated by ....

FIGURE 41.—Form used for tabulating kite records

indicated to two decimal places. The absence of a (+) or (−) ı signifies a decrease in temperature with height, and a (−) sign cates an increase in temperature with height, i. e., an inversion.

)9. Under " remarks " are recorded all phenomena observed durthe flight, such as clouds, halos, precipitation, thunderstorms, etc.

10. Whenever kites are observed to enter a cloud base, the eleva- angle of the kite and length of wire out are noted and the cloud ude determined trigonometrically. (See paragraph 205.) This e is added to the station elevation and the next lowest 50 meters aken as the cloud height, except when the value is 500 meters ess, when the next lowest 25 meters is used. This method is stituted for that in which 2 per cent is deducted, referred to Section IX, paragraph 183.

AIRPLANES

XII. GENERAL DESCRIPTION

211. Aerological observations by means of airplanes have a number of importance advantages over kite observations, viz:

(*a*) The time required for a plane to reach a given height is considerably less than for a kite.

(*b*) Flights can be made by plane during calms and very light winds.

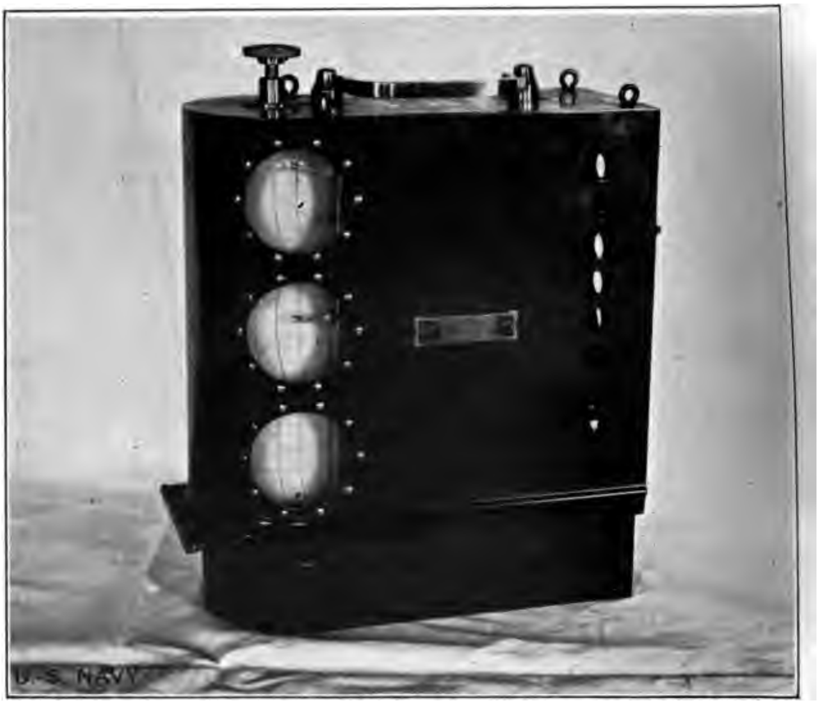


FIGURE 42.—Aero-meteorograph with cover closed

(*c*) The possibilities of flying a plane are greater than those of flying a kite during the occurrence of precipitation.

(*d*) Greater heights can be reached by plane.

(*e*) Eye observations of the upper limits of clouds, haze, fog, etc., can be made from a plane.

There are some conditions, however, that are peculiarly dangerous for airplane flights, but that present no especial difficulty to making soundings by kites or balloons. Principal of these are heavy snowstorms and dense fogs, the almost entire lack of visibility attending them making take-off and landing of airplanes practically impossible.

212. In order to procure accurate records the plane should not mb faster than 200 to 250 meters per minute. Also, it should vel off " for 1 minute or more at approximately every 500 meters. e descent can be made as rapidly as desired unless the descent tion of the record is to be used, in which case, the same speed uld be maintained as for the descent.

XIII. AERO-METEOROGRAPH

13. The instrument used in airplane observations is called an o-meteorograph. (Figs. 42 and 43.) The complete mechanism nclosed in a nonferrous metal case, hinged to the base and per- ated to allow free circulation of air. It records simultaneously pressure, temperature, and humidity of the atmosphere and is cially adapted for use on airplanes and dirigibles.

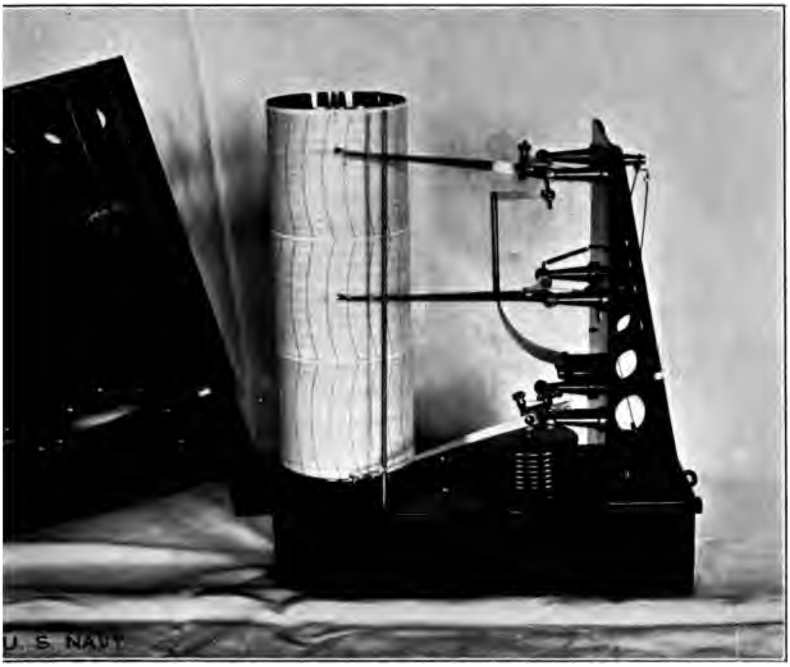


FIGURE 43.—Aero-meteorograph with cover lifted

214. Figure 42 shows the instrument with its cover and Figure 43, th its cover removed. The instrument, including the cover, weighs kg. (6.2 lbs.). The base, 9½ inches long and 4 inches wide, is de of formed sheet brass and is constructed for greatest rigidity. the under side of the base a clock is fastened which controls the ne-movement of the upright chart cylinder to which it is directly ared. This cylinder revolves about a tapered shaft of phosphor nze, securely clamped to the base.

215. A chart, Figure 44, adapted for a 6-hour triple record is attached to the surface of the cylinder and is held in place by a metallic clip. The three pens which trace the meteorological record are controlled to an accurate recording movement, since the axes of the pen arms are supported individually on upright columns of sheet brass suitably channeled and tapered, thus precluding distortion or displacement. It will be noted that the pressure scale decreases upward and that the range of the humidity pen is considerably greater than on the kite meteorograph; also, that the scale values of all three elements are linear.

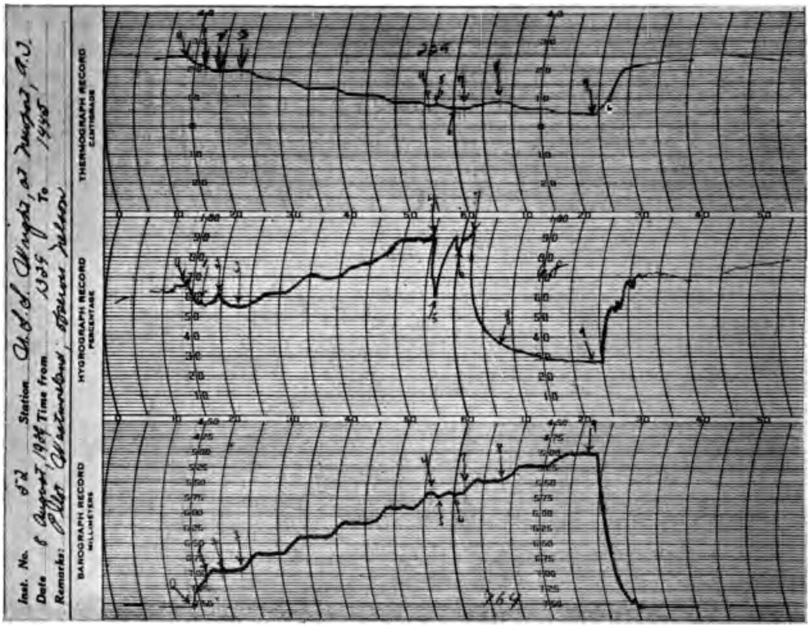


FIGURE 44.—Aero-meteorograph record of flight made by the United States Navy on August 8, 1929, U. S. Wright at Newport, R. I.

216. *The pressure, temperature, and humidity elements* are of the same type used on the kite meteorograph. (See Section VI, paragraphs 63 to 65.) The temperature element shown in Figure 43 is of the Bourdon type but the newer instruments are now equipped with bimetallic temperature elements as in the kite meteorographs. The movement of the pressure element is transmitted directly to the pen arm and records changes in pressure between 775 and 450 millimeters, corresponding to an altitude of about 4,300 meters. Greater heights can be recorded by adjustment of the pen range. The range

f the temperature pen is from −30° to 40° C. The setting of the ens is controlled by a thumb nut located on the pen arms so that hey can readily be set to agree with the standard instruments.

217. The aero-meteorograph must be mounted on the plane where it will be unaffected by heat from the motor, exhaust, or cockpit. Figures 45 and 46 show two methods of mounting these instruments used by the Navy Department. Vibration is eliminated by the use f elastic cord. Figure 47 shows a method of mounting used for btaining records during conditions favorable for the formation of ce on airplanes. It will be noted that in the latter, the instrument s carried inside a special container so as to protect it from ice as uch as possible. Figure 48 shows the instrument being placed nside this container.

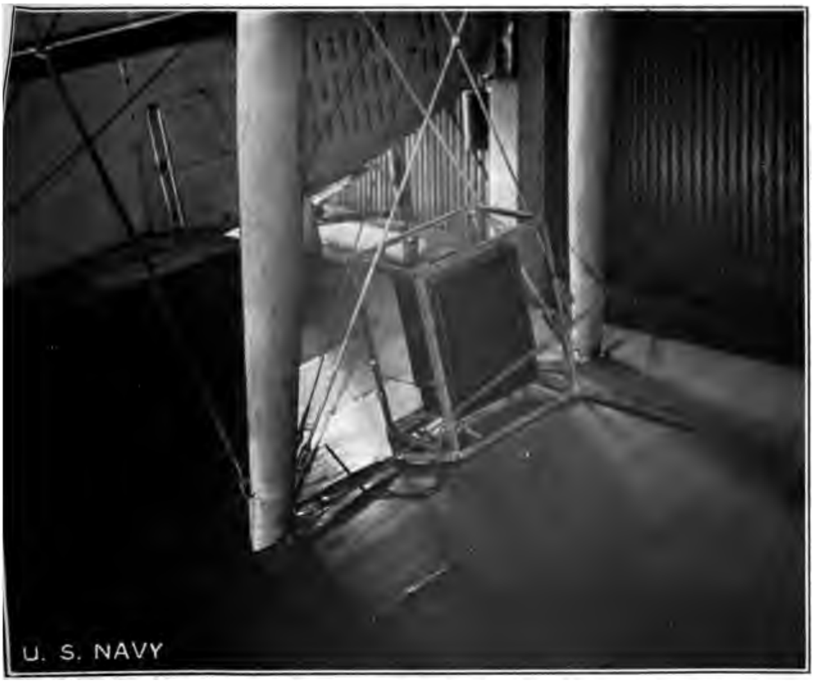


FIGURE 45.—Aero-meteorograph mounted on a Navy plane

218. Aero-meteorographs are calibrated with the same apparatus at is used for kite meteorographs. As a rule, the calibrations are ade to agree with the printed scales on the record sheet, but in me cases it is found more desirable to calibrate them like kite eteorographs, i. e., disregarding the printed scales.

219. The aero-meteorograph records are computed in the same eneral way as the kite records. However, when the calibrations are ade with reference to the printed scales on the record sheet, it is not ecessary to draw and compute base-lines. When the calibrations re made without reference to the printed scales, base-lines are drawn nd the records computed exactly as are the kite records. (See g. 44.)

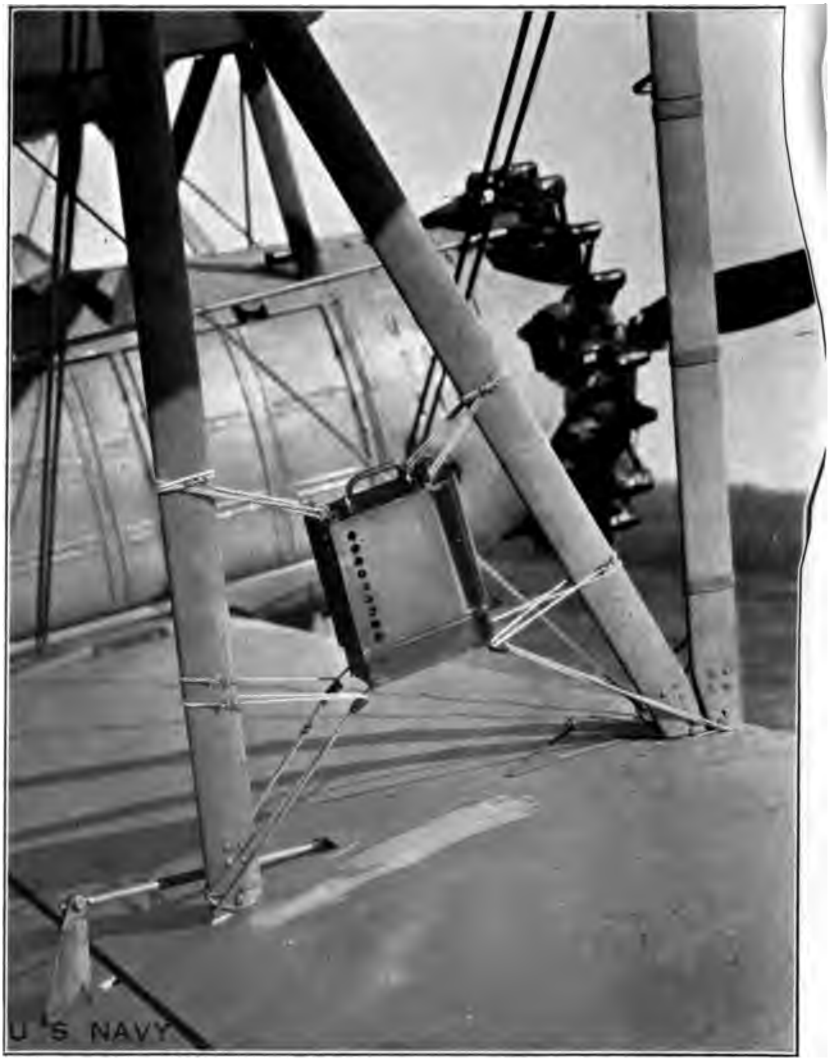


FIGURE 46.—Aero-meteorograph mounted on a Navy plane

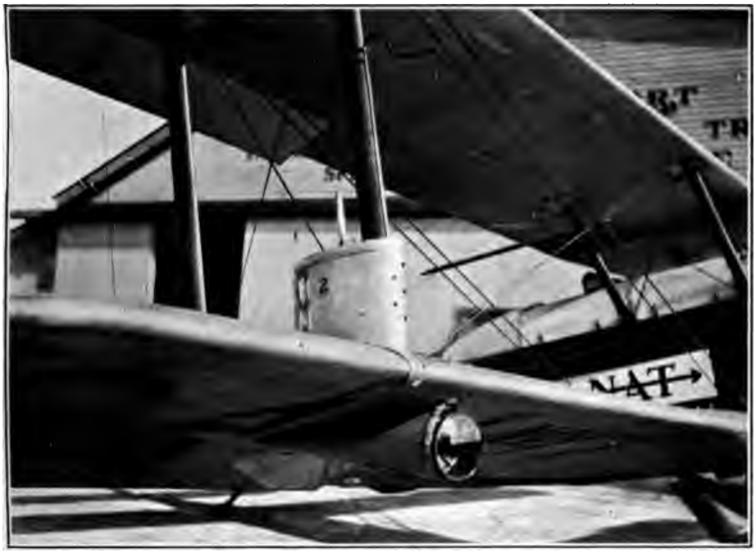


FIGURE 47.—Aero-meteorograph mounted for use in conditions favorable for the formation of ice on airplanes

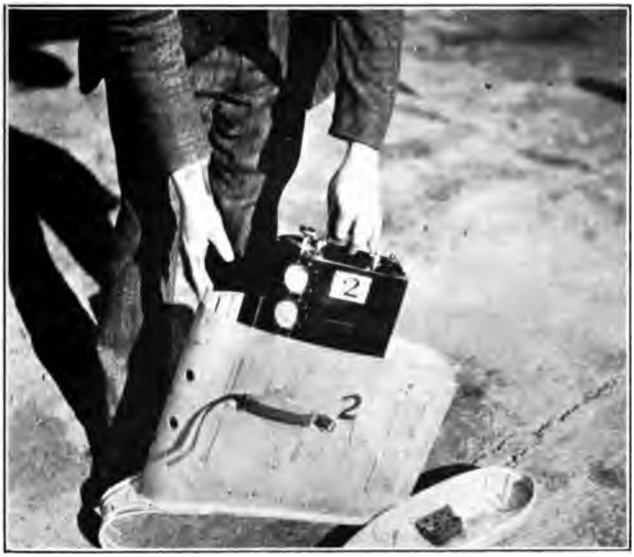


FIGURE 48.—Special container used for mounting aero-meteographs for observations during conditions favorable for the formation of ice on airplanes

SOUNDING BALLOONS

XIV. GENERAL DESCRIPTION

220. Sounding balloons are used to carry meteorological instruments to the greatest heights attainable. In general, the heights reached are about 15 km., but with extra good balloons, heights exceeding 30 km. are occasionally attained. Sounding balloon observations are usually made by the Weather Bureau each year during the International Month, designated as such by the International Commission for the Exploration of the Upper Atmosphere. Also, special series are sometimes made to obtain data for studies of upper air conditions during the prevalence of certain types of pressure distribution.

XV. SOUNDING BALLOON METEOROGRAPH

221. The Fergusson meteorograph [9] is used by the Weather Bureau in sounding balloon observations. (Fig. 49.) Two of the most important features of this instrument are:

(*a*) Its light weight, viz, between 190 and 200 grams (7 oz.), including the cover.

(*b*) The double traverse of the pressure marker.

Other features are its simplicity and economy in construction, its strength and rigidity to withstand customary hard usage, and its clear and accurate records. The instrument is 8¼ inches long, 3½ inches wide, and 4½ inches high.

222. *The pressure element* is a vacuum Bourdon tube. A specially contrived link-motion controls the marker arm which, with its reversing movement, traces a record double the extent of the pressure space on the record sheet. The range of the recording style is nearly one atmosphere.

223. *The temperature element* consists of a thin piece of thermostatic metal, made of invar and bronze which are electrically welded together and bent into a nearly circular shape. The temperature element is shielded from direct sunshine and insulated from heat radiation by being placed in a double-walled tube. The temperature scale is approximately 1 millimeter on the record sheet to each 1.8° C.

224. *The humidity element*, consisting of eight separate strands of human hair with a reclaiming spring to maintain constant tension, is mounted in the same tube with the temperature element. The range from zero to 100 per cent humidity is through approximately 15 millimeters.

225. *The clock*, which rotates the cylinder to which the record sheet is attached, is especially constructed to reduce weight and is adapted to limit the revolutions of the cylinder to the time period of the actual flight, thus preventing unnecessary and confusing records after descent.

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[9] Fergusson, S. P., New Aerological Apparatus, Monthly Weather Review, June, 1920.

26. *The cylinder* has a circumference of 180 mm. (7.1 in.) and 5 mm. (3 in.) high. The axes of the three recording markers so located at the same height above the base that the markers re the same time-arc on the cylinder. The latter makes one comte revolution per hour.

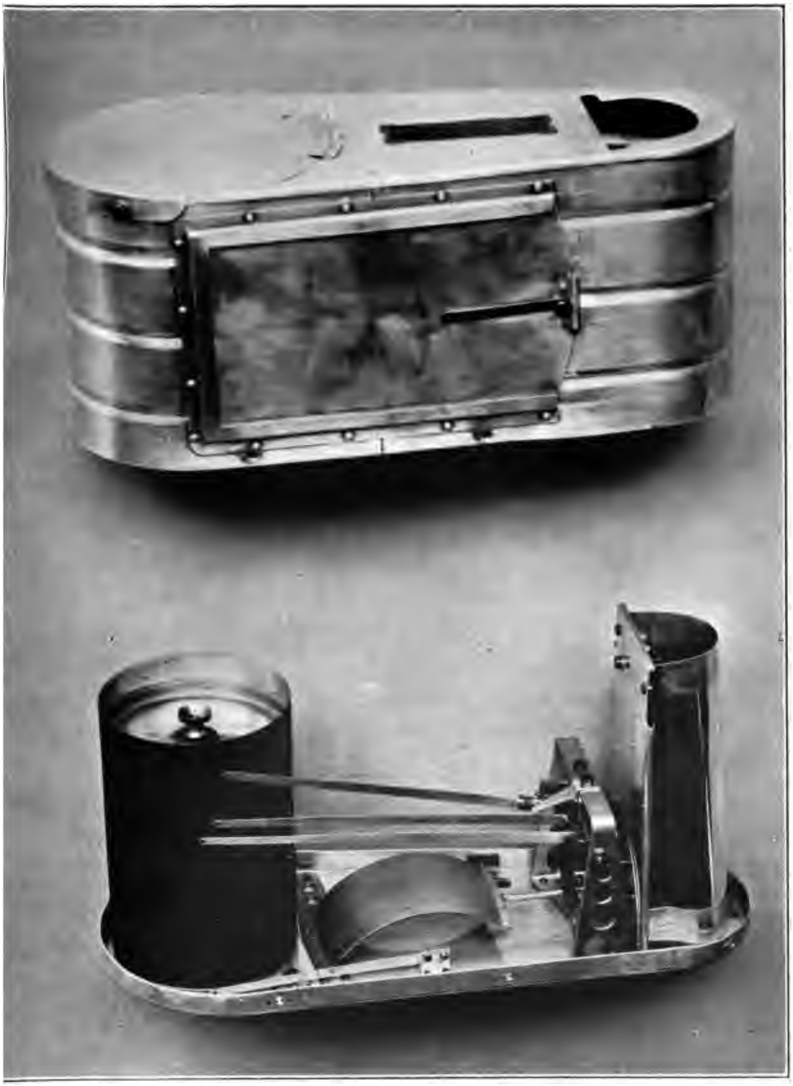

Figure 49.—Fergusson sounding balloon meteorograph and cover

227. *The record* is traced on a smoked aluminum sheet and not engraved paper. The observed tracings are afterwards measured d reduced by means of comparative tests with standard instrunts. (See Sec. XVI.)

228. The whole mechanism is inclosed in a polished aluminum case (see fig. 49) constructed with a sliding door to give easy access to the apparatus within. There is an additional opening above through which the clock can be wound and the cylinder, together with the record sheet, removed.

XVI. CALIBRATION OF METEOROGRAPHS

229. These instruments are calibrated for pressure in a special apparatus (fig. 50) which permits a simultaneous reduction of temperature, simulating atmospheric conditions from the surface to the heights reached by the balloons. This method is necessary because of the extremely low temperatures encountered at high altitudes. This type of chamber was designed by the National Advisory Committee for Aeronautics at Langley Field, Va.[10]

230. The apparatus is composed of an upper and lower section. The legs are fastened to, and are a part of, the upper section, the lower section being movable in the vertical direction and counterbalanced by a suitable weight in the rear.

231. The upper section supports, and thermally insulates, a circular cast iron plate which supports the instrument rest, the air circulating blower, the cooling coils, the high pressure expansion valve, the heat interchanger and the automatic relief valve. All air and electrical connections pass through the iron plate which forms the top side of the air-tight chamber. This cast iron plate is ribbed to prevent distortion, and has a thick annular ring finished to accommodate a glass bell jar 12 inches in diameter.

232. The cooling coil consists of 30 turns of ⅜-inch (O. D.) copper tubing having a length of 62 ft., and furnishing 6 sq. ft. of radiating surface.

233. The lower section of the cabinet houses the inverted bell jar, the open edge of the bell jar being ground to a plane surface. When this section is raised, the jar comes in contact with the lower surface of the iron plate and forms an air-tight joint. This seals the chamber.

234. The size of the chamber and bell jar is such that six Fergusson balloon meteorographs can be calibrated at the same time. A suitable observation window is placed in one side of the cabinet to enable the operator to observe any visible change or read any instrument that may be placed within. The glass bell jar is insulated with cork board 4 inches thick at its thinnest section.

235. The carbon dioxide (CO_2) tank is supported in a wooden rack adjacent to the altitude chamber. The valve of the tank is down, in order to force the liquid to the chamber expansion valve.

236. Temperatures as low as −50° C. can be attained with this apparatus. It is not practicable, however, to use it for the calibration of the temperature elements, the latter being calibrated by immersion in an alcohol bath. The temperature of the alcohol is reduced by placing compressed carbon dioxide (dry ice) in it and mixing thoroughly. Temperatures of −70° C. and lower are thus

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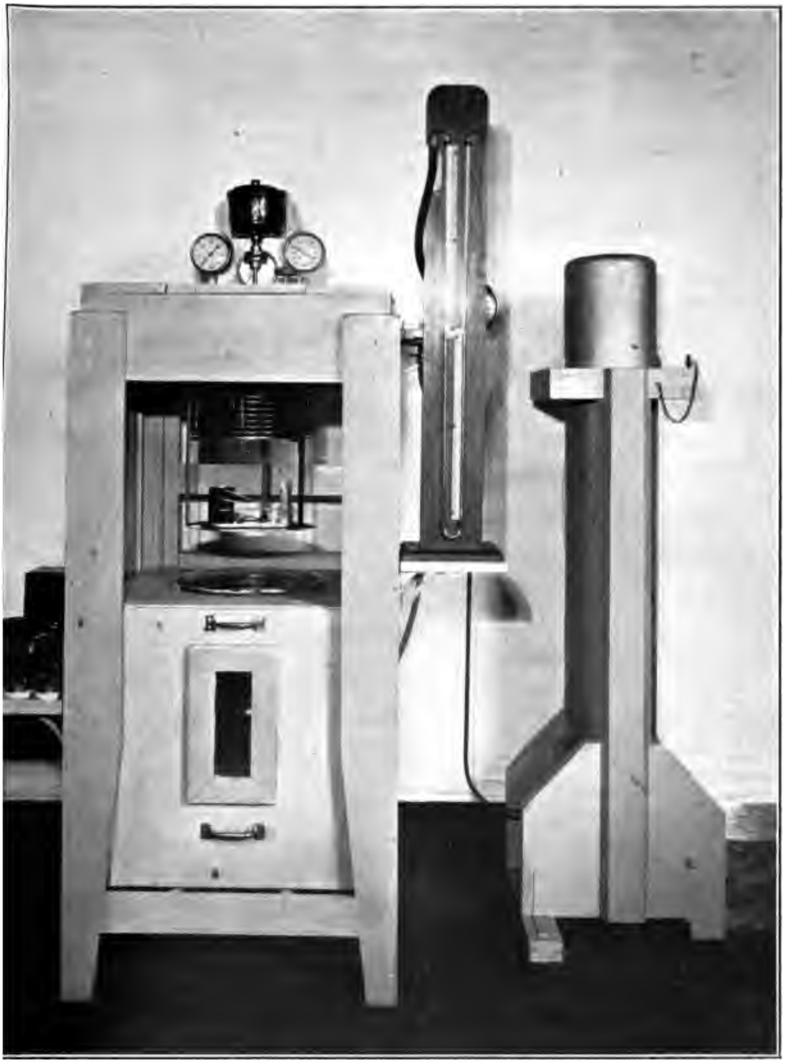
[10] Technical Notes, National Advisory Committee for Aeronautics, No. 229. An Altitude Chamber for the Study and Calibration of Aeronautical Instruments. By H. J. E. Reid and O. E. Kirchner.

sible of attainment. The instruments, with clock running, are mersed just sufficiently to cover the temperature element and are d in the bath until the temperature marker shows the element to ve become properly adjusted. The temperature is then read from standard thermometer which is also immersed in the bath. Immer-



IGURE 50.—Altitude chamber used for pressure calibration of sounding balloon meteorographs

ns are made at approximately the following temperatures: −75° C., 50° C., −25° C., 0° C., and 25° C., the two latter immersions being de in a melting ice and water bath, respectively.

237. The humidity elements are calibrated by placing the instru- nts inside the humidity chambers used for kite meteorographs.

The relative humidity is adjusted to a minimum and maximum, with several intermediate values, and the instruments are subjected to these conditions and the positions of the marker noted with reference to the psychrometer readings.

XVII. MAKING THE FLIGHTS

238. *The balloons* used are seamless rubber, 40″ in diameter, capable of expansion to between two and three times their normal diameter, and weigh between 800 and 1,000 grams.

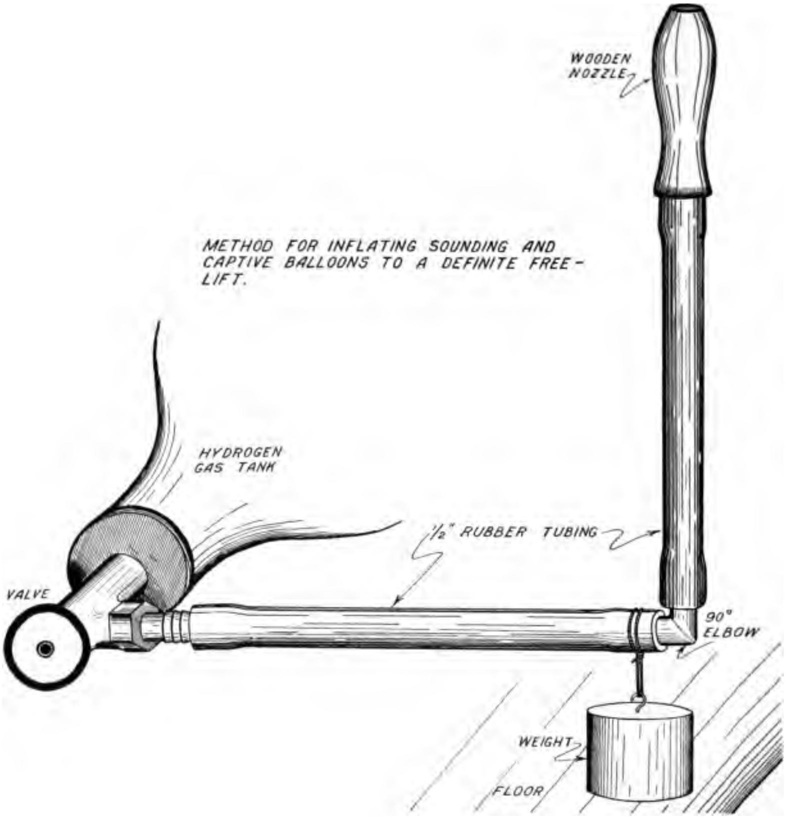

WOODEN NOZZLE
METHOD FOR INFLATING SOUNDING AND CAPTIVE BALLOONS TO A DEFINITE FREE-LIFT.
HYDROGEN GAS TANK
½″ RUBBER TUBING
VALVE
90° ELBOW
WEIGHT
FLOOR

FIGURE 51.—Inflation device for sounding and captive balloons

239. *Care of balloons.*—It is very important that these balloons never be placed near any heated object, such as a radiator, stove, etc. They should be kept well dusted with a very fine grade of soapstone or talc. This serves to prevent the rubber surfaces from sticking together and also prevents oxidation of the surface of the rubber. They should be kept in as cool (not cold) a place as possible and especially away from direct sunlight. They should not lie in one position with the same surface in contact all the time, but should be turned or handled about every two weeks.

240. The balloons must be inflated indoors so that wind or rain will not interfere with obtaining the proper free lift. On account of the

size of these balloons after inflation (60 inches diameter, approximately), it is necessary to have a wide door to pass through. A garage is generally well suited for this work.

241. *Inflation of balloons.*—The balloons are inflated with pure hydrogen gas to a free lift such that the balloon will rise at a rate of about 200 meters per minute. The extreme limits of the ascensional rates are 150 and 300 meters per minute, below or above which the records are not considered accurate. The free lift required is dependent upon the size and weight of the balloon and the weight of the equipment to be carried. Usually the free lift is from 500 to 600 grams for Weather Bureau equipment. After this has been determined the balloon is inflated to this "definite free lift" by means of the apparatus shown in Figure 51.

242. The procedure is as follows: After expelling all the air from the balloon the neck is placed over the wooden nozzle and the balloon is inflated with hydrogen until the suspended weight is just lifted from the floor. This suspended weight should be equal to the required free lift plus the weight of the meteorograph and accessories (exclusive of the weight of uninflated balloon), less the weight of the rubber tubing and nozzle. Example:

	Grams
Required free lift	500
Weight of meteorograph, basket, parachute, etc	262
Weight of rubber tubing, nozzle, etc. (lifted by balloon when inflating)	83

In the above case the suspended weight should be 679 grams, i. e., the sum of the first two figures minus the third figure. The "total lift" in this case would be 762 grams plus the weight of the uninflated balloon.

243. In case any pinholes develop in the balloon during inflation, they should be patched with the special rubber cement made for use with these balloons. However, the liquid cement must not come in contact with the balloon. The patch should first be coated with the cement and then allowed to become thoroughly dry. The surface of the balloon should be washed with water to remove all traces of dust or powder. The patch is then applied to the balloon.

244. *Precautions against explosions.*—It is a well-known fact that hydrogen and air when mixed in the proper proportion are highly explosive. Therefore, the following instructions should be rigidly enforced:

(*a*) Smoking should be prohibited at all times in, or near, the room where the balloons are inflated or where hydrogen is stored.

(*b*) Whenever a balloon, during the process of inflation, is found leaking it should be detached at once, taken outdoors, and exhausted of hydrogen in the open air.

(*c*) In case a balloon bursts while being inflated, all doors and windows of the room should be immediately opened so the hydrogen may escape.

(*d*) So far as possible, doors and windows of the room should be kept open whenever a balloon is being inflated.

(*e*) A suitable sign, somewhat as follows, "Danger—No Smoking," should be posted in a conspicuous place where the balloons are inflated or hydrogen stored.

245. *Smoking the record sheet.*—The record sheet is attached to the cylinder by interlocking the folded edges. The sheet is then smoked by holding it over a gum-camphor flame. To do this a rod is passed through the cylinder and the latter is then turned rapidly so that it will be smoked evenly. The coating must completely cover the record sheet but not be so thick that the styles will not penetrate it.

246. *Oiling meteorograph.*—Place a small drop of kerosene on all pivots and bearings of the meteorograph (including the clock) just previous to the observation. Any other oil will congeal when the low temperatures of the stratosphere are encountered. To do this the clock must be removed. When the clock is secured to the base after oiling, the screws by which it is fastened should never be turned tight, as this may place it out of alignment and cause it to stop.

247. When the clock has been replaced after oiling, the cylinder with its smoked record sheet is placed on and secured to the clock spindle. The clock should be wound and started just previous to placing the markers against the record sheet. The meteorograph markers must press against the smoked record sheet with just the proper tension; too much tension will cause excessive friction, and too little will result in loss of record. The test for proper tension of the markers is made by holding the instrument so that the markers are underneath and observing whether they just leave the record sheet when the instrument is slightly tapped.

248. The instrument must be allowed to become properly adjusted to outdoor conditions before releasing (from 15 to 30 minutes being necessary) and therefore it should not be held in the sun or too close to the observer's body. At times of insufficient wind, the instrument should be fanned so that the true surface conditions will be recorded.

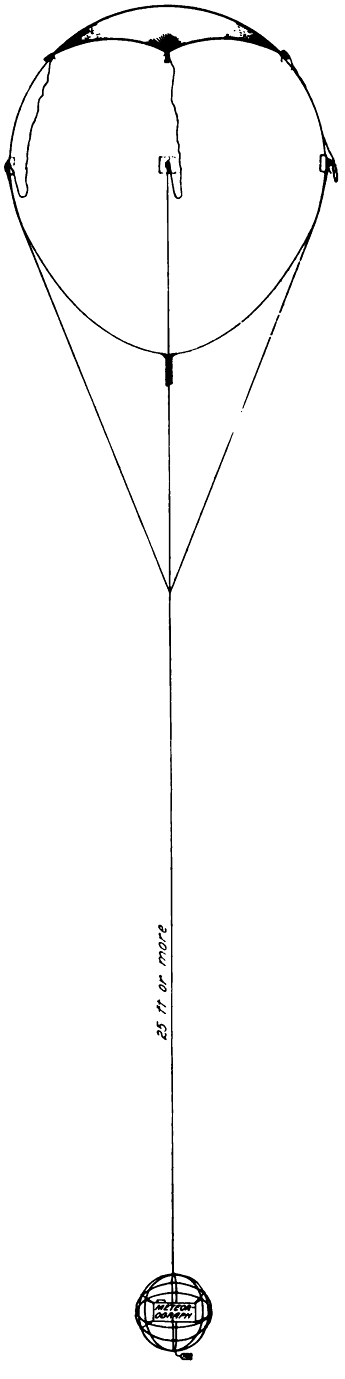


FIGURE 52.—Method of attaching meteorograph and parachute to sounding balloon

249. *Parachute.*—A square yard of bright red silk is fastened to e top of the balloon to act as a parachute after the balloon bursts nd also to attract attention after the equipment lands. A cord tied from each corner of the parachute to a lug on the balloon ith sufficient slack to allow for expansion of the latter.

250. *Fastening meteorograph to balloon.*—The meteorograph is ied in the wicker basket in the following manner:

From each of the lugs on the instrument, tie a cord to an interection on the basket. This must be done carefully so that all of he cords remain taut and the instrument remains in the exact cener of the basket. The latter is hung at least 25 feet below the alloon as shown in Figure 52.

251. *A return tag* is attached to the basket requesting the finder o pack the instrument carefully and return it by express (collect) or which payment of a few dollars is made.

252. *Releasing the balloon.*—This is easily accomplished when the ind is light but great care is necessary during strong winds. If his is done from the top of building the leeward side should be sed and care taken so that the instrument does not strike any bject. When the balloon is released from the ground during high ind, it is advisable to run *with the wind* as fast as possible and elease the balloon when it is in as nearly a vertical position as ossible.

253. Sounding balloons are generally released about one hour bere sunset so as to avoid, as much as possible, the vitiating effects f insolation. Night observations would, of course, entirely elimite such effects, but since it is desirable to follow the balloon with o theodolites it is necessary to have daylight conditions.

254. The following data should be recorded when making a soundg balloon observation:

(*a*) Elevation above sea level of both the point of release and of the station barometer.
(*b*) Time balloon is released.
(*c*) Serial number of meteorograph.
(*d*) Weight and size (diameter) of uninflated balloon.
(*e*) Weight of meteorograph and accessories (excluding balloon).
(*f*) Diameter of inflated balloon.
(*g*) Free-lift (see paragraph 242).
(*h*) Time of "markers down" (should be a few minutes before release).
(*i*) Dry and wet bulb thermometer, station pressure, relative humidity, surface wind velocity and direction, clouds and any unusual phenomena at the time of release.

255. *Theodolites.*—If possible, the balloon should be followed with o theodolites, using a base line of several kilometers in length nning as nearly as possible at right angles to the general direction at the balloon is expected to travel. If two theodolites are imacticable, one theodolite should be used. Whenever two theodoes are used, the time rate (mm./hr.) of the meteorograph clock ould be determined within the 24 hours preceding the observation. he time rate should be referred to the same timepiece used in aking the two theodolite readings. In 2-theodolite observations

it is of the utmost importance to read both instruments simu taneously. To do so it is necessary to have a suitable signal devic either electrical or visual.

256. *Return of metorographs.*—When the metorographs are r turned to the station the cylinder containing the smoked recor sheet is very carefully removed and the latter (while still on th cylinder) is immersed in a solution of “ fixatif.” When dry, th record sheet is very carefully removed from the cylinder. Figu 53 shows an actual sounding balloon record.

257. *The percentage of returns* depends largely on the region i which the balloons are released. In fairly well populated sectio this usually amounts to about 90 per cent. They usually land wit in 50 miles, but occasionally several hundred miles away. To insu the greatest percentage of returns, action should be taken to ha suitable announcements in the press and, if possible, by radio, inforn ing the public of the observations and the payment offered for tl return of the equipment.

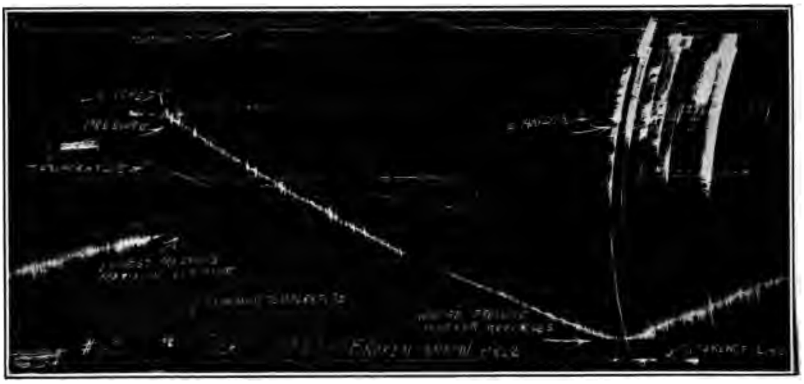


FIGURE 53.—Sounding balloon record of December 1, 1929, Broken Arrow, Okla.

258. *Precautions to insure a good record.*—The details of prep ration in sounding balloon work are of the greatest importance, the omission of any one may result in failure to secure a reliab record. Particular care should therefore be taken in regard to pa graphs 246, 247, and 248. As a final precaution the observer rele ing the balloon should make certain that the styles are marki properly and the clock is wound and running.

259. *Computation of records.*—The sounding balloon records a computed in the same way as the kite records. Base lines are dra and the ordinates of the various elements are measured with a pa of draftman's dividers and a millimeter scale. The computed da are then tabulated and interpolations made for the standard leve as in kite work. Computed heights are compared with the resu of 2-theodolite observations. Wind velocities and directions a determined in accordance with instructions for making pilot ballo observations, Weather Bureau Circular O, 1928. When only o theodolite is used the computations of wind data are based on t heights determined from the meteorograph record sheet.

LIMITED-HEIGHT SOUNDING BALLOONS

XVIII. GENERAL DESCRIPTION

260. Limited-height sounding balloons are used when winds are too light for kite flying. The method is also advantageous in isolated regions and over water areas where regular sounding balloons landing considerable distances away are not likely to be found.

261. *Balloons.*—The regular sounding balloons are used for these observations. (See Sec. XVII, par. 238.) No parachute is necessary, however, as the balloon deflates gradually and therefore serves as a parachute itself.

262. *Meteorograph.*—The Fergusson sounding balloon meteorograph (see Sec. XV), is readapted for this work by replacing the smoked record sheet with a ruled paper sheet and the pointed markers with pens for use with ink. The kite record sheet, Form 1101 (fig. 19), is trimmed down to fit the balloon meteorograph cylinder. The humidity space on Form 1101 is not used, however, the ordinates for this element being of the same size as those for pressure and temperature. The double-traverse arrangement of the pressure mechanism is removed as the comparatively lower heights reached by this method make such an arrangement unnecessary. The same calibration apparatus is used as for kite meteorographs. (See Sec. VII.)

263. *Deflation device.*—The device used for deflating the balloon at a predetermined altitude is the Rossby deflation valve. (Fig. 54.) This is made of aluminum, weighs 40 grams, and fits into the neck of the balloon. The valve is normally kept open by means of a spring but when inserted in a balloon it is held closed by means of a cord tied to the lower end of the stick as shown in the figure. When this cord is released, the valve opens and the balloon deflates. The cord is drawn through a piece of blasting fuze in the manner shown. This fuze, which burns at a known rate, is lighted at its lower end just before releasing the balloon. Knowing the approximate rate of ascent and the rate at which the fuze burns, the height at which the thread will be burned is readily determined by the length of fuze used. The fuze burns at the rate of 2½ minutes per meter and weighs 22 grams per meter.

264. A possible improvement over the use of fuse for opening the Rossby deflation valve has been proposed, but not as yet tried. This depends on the expansion of an aneroid cell which would open the Rossby valve at any predetermined altitude.

265. *Theodolites.*—The balloon is followed with one theodolite (occasionally two) and free-air wind directions and velocities determined. When only one theodolite is used the altitudes for successive minutes are determined by dividing the altitude difference between two computed levels by the time interval in minutes.

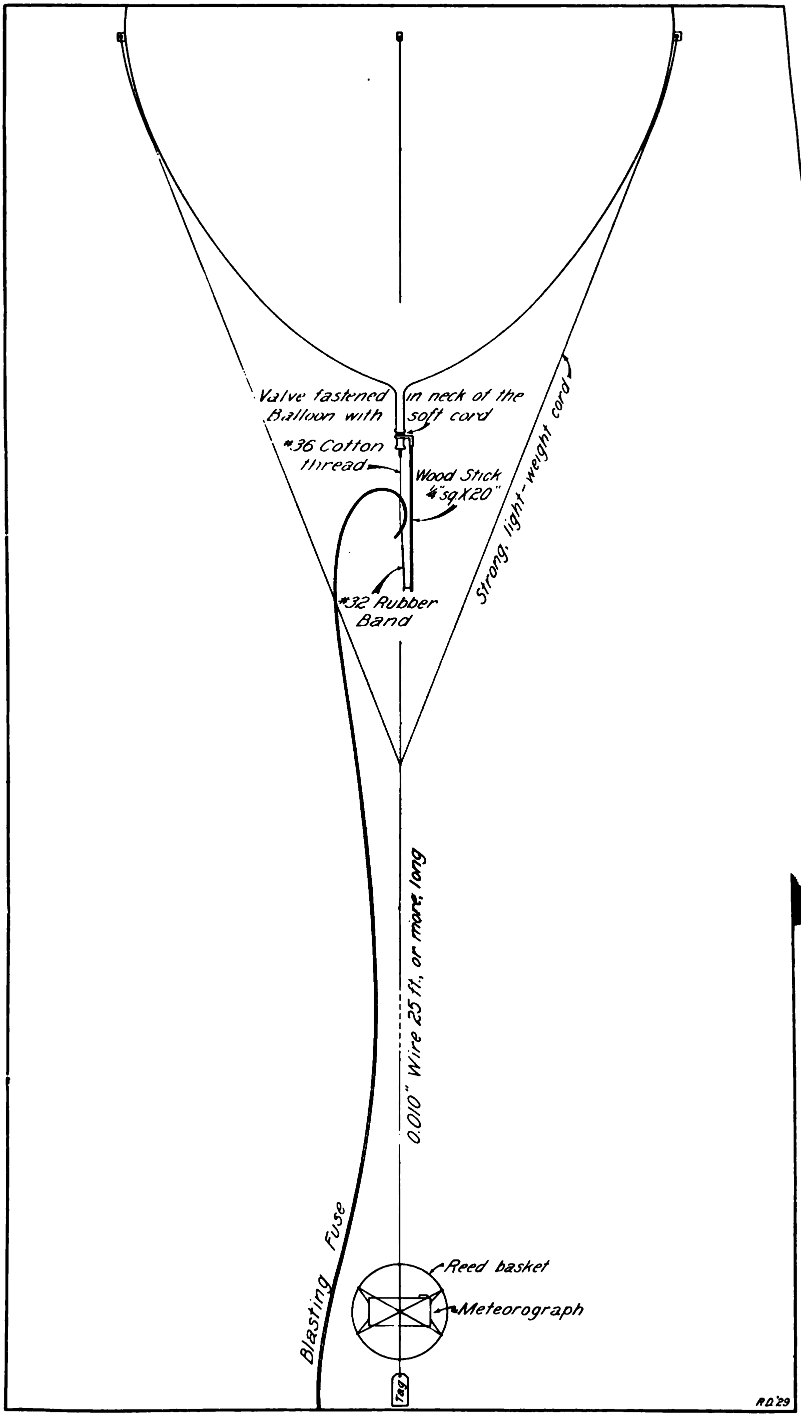


FIGURE 54.—Method used for attaching Rossby deflation valve to sounding balloon

66. *Surface observations.*—Readings of the surface temperature, nidity, wind direction, clouds, etc., are made at approximately ninute intervals during the flight, unless marked changes occur in of these elements, when more frequent readings should be le.

7. *Computation of records.*—The records are computed in the e way as are kite records. (See Sec. XI.)

8. *Recovery of equipment.*—The altitude at which these balloons isually set to deflate is approximately 3 km. With light winds, obvious that the balloon will not fall very far away and the tice is to start out immediately for it after determining its oximate location from the theodolite readings. In some cases s been found advantageous to start out before the balloon is sed, in the general direction that the balloon is expected to l. It is then possible to keep the balloon in sight until it lands. n aid in locating the equipment, a pilot balloon is fastened to arge balloon with a cord 75 feet or more in length. The pilot on must be inflated sufficiently so that it will rise faster than arge balloon so as to prevent interference with the instrument. will then serve to attract attention after the equipment has ed.

9. *Return tag.*—As a precaution against the equipment not being d as readily as expected or in case the deflation valve fails to tion, a return card should always be attached, similar to that used egular sounding balloon work. (See Sec. XVII, par. 251.) ever, in case of limited-height sounding balloon observations, payment offered for the return of the equipment does not narily exceed $1.

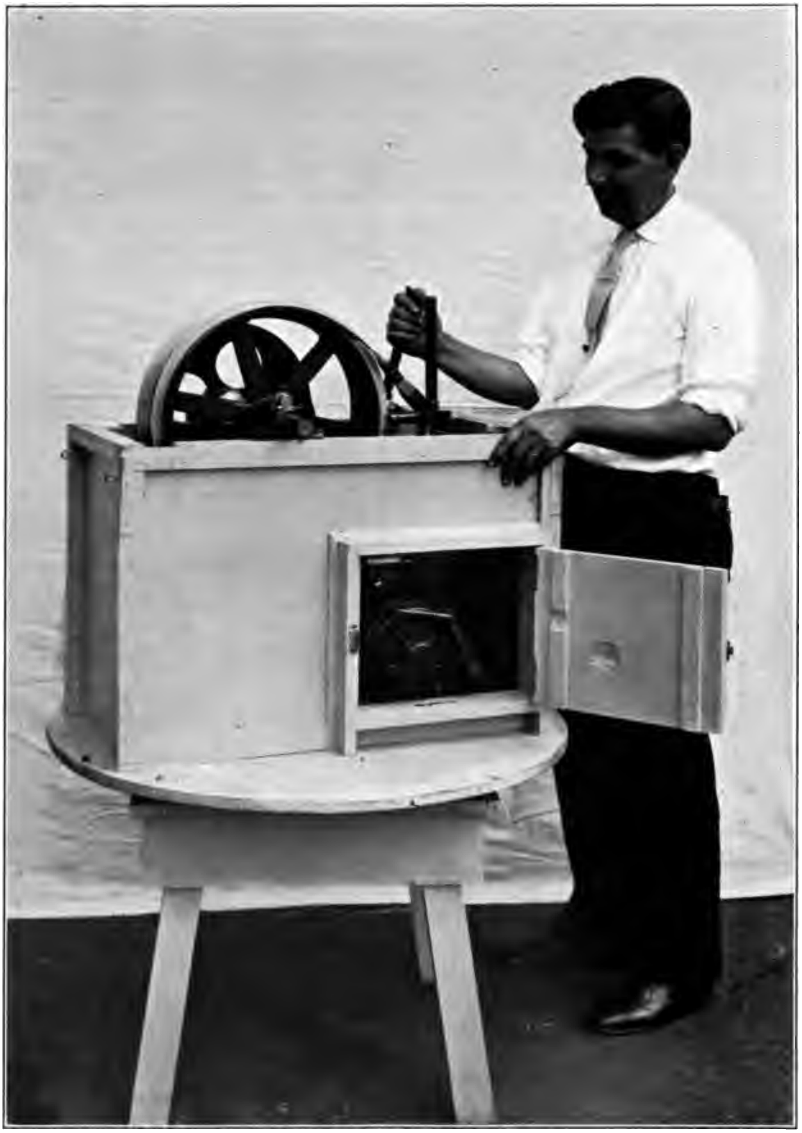


FIGURE 55.—Free-rising captive balloon reel

FREE-RISING CAPTIVE BALLOONS

XIX. GENERAL DESCRIPTION

270. Another method of obtaining upper air data when winds are too light for kites is to use free-rising captive balloons. Best results are usually obtained with wind velocities ranging between calm and 5 or 6 meters per second. Considerable caution is necessary with winds between 6 and 10 meters per second, while real danger of a breakaway is encountered with winds between 10 and 12 meters per second, especially with the 0.008-inch wire.

271. *Balloon and meteorograph.*—The same kind of balloon and meteorograph is used as in limited-height sounding balloon observations. (See Sec. XVIII, par. 261–262.) A pilot balloon similar to that used with limited height sounding balloons can be used in case of a breakaway. (See Sec. XVIII, par. 268.)

272. *Reel.*—The type of reel used is shown in Figure 55. It is fitted with an adjustable speed, reversible motor, designed for single-phase current. The reel table can be turned to accommodate any wind direction.

273. *Protection against lightning.*—The balloon reel must be well grounded for protection against lightning and atmospheric electricity. (See Sec. III, par. 17.)

274. *Fastening balloon to wire.*—Four cords from the lugs are tied at a point from 4 to 6 feet below the neck of the balloon, and a fifth cord is tied from the neck to this junction. This gives stability and helps hold the balloon in normal position in case one of the lugs breaks. Also, it reduces the strain on the lugs without endangering the neck of the balloon. From this junction a cord is tied with about 1 foot of play into the ring on the wire. (See fig. 56.) It will be noted that the end of the wire is run through a piece of small copper tubing and the latter twisted into a loop as illustrated.

275. The basket containing the meteorograph should hang at least 25 feet below the balloon in order to avoid the air in the immediate wake of the balloon. Vibration

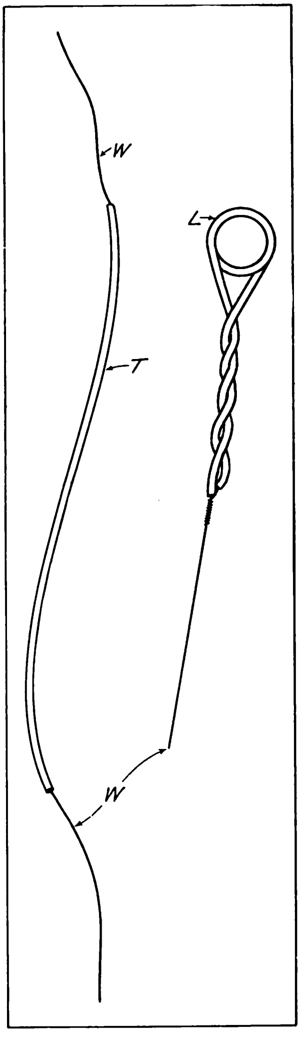


FIGURE 56.—Method used for attaching wire to captive balloon (W, wire; T, very small copper tubing; L, loop made with copper tubing after inserting wire into which cord from balloon is tied)

of the instrument, which sometimes occurs when the balloon is being reeled in, can be greatly reduced by using a strong rubber band between the basket and the end of the wire or cord which is tied to the basket. To insure against this rubber band's breaking, a slack piece of cord should also be tied to the basket.

276. In order to keep the slack wire off the ground, the reel is mounted on an elevated platform. (See fig. 57.) This platform is sometimes built on the roof of the kite reel house as shown in figure 58. Best results are usually obtained by reeling the wire out sufficiently rapid so that the balloon rises free from all restraints except the gradually increasing weight of the wire. At the beginning of the observation when reeling the wire out rapidly it is necessary to use special care to prevent the wire from jumping off the drum and kinking. The wire should not be reeled out at full speed until the balloon is far enough to one side of the platform for the wire to sag into the open field smoothly.

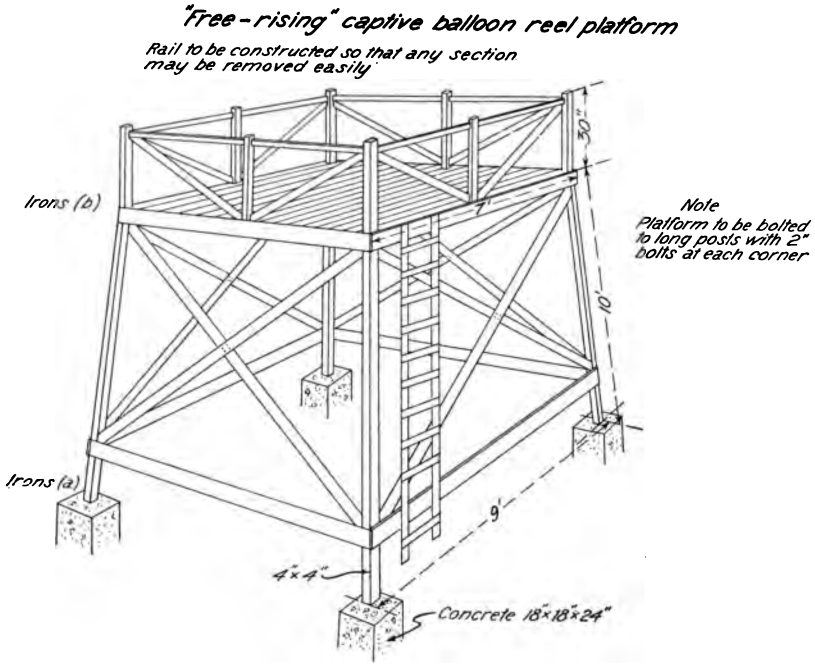

"Free-rising" captive balloon reel platform
Rail to be constructed so that any section may be removed easily
30"
7'
Irons (b)
Note
Platform to be bolted to long posts with 2" bolts at each corner
10'
Irons (a)
9'
4×4"
Concrete 18×18×24"

FIGURE 57.—Platform used for making free-rising captive balloon observations

277. ***Wire.***—Steel music wire, 0.008, to 0.012 inch inclusive, (Sec. IV, par. 29), is used in these observations. As in the case of kite wire, the balloon wire should be kept oiled, especially after being exposed to clouds and not allowed to become kinked. When not in use the balloon reel must be kept securely covered. (See Sec. IV, par. 34.)

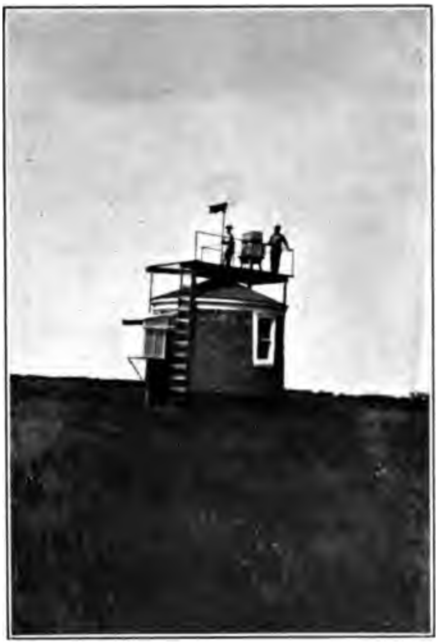


FIGURE 58—Platform built on roof of kite reel house for making free-rising captive balloon observations

278. *Caution against breakaways.*—The balloon should never be permitted to penetrate a solid cloud layer when the wind conditions above the clouds are not definitely known. Whenever strong winds aloft are unavoidably encountered the balloon should be reeled in very slowly and cautiously to prevent a breakaway.

CEILING BALLOONS

XX. GENERAL DESCRIPTION

279. Ceiling balloons are used chiefly to measure the altitude of clouds when the latter are in general less than 1000 ft. high and cover all, or nearly all, of the sky. The determination of cloud heights by this method is based on a definite free lift and the resulting uniform ascensional rate of the balloon, the latter being followed by eye (without instrument) until it enters the cloud base.

280. *Balloons.*—Ceiling balloons are from 4 to 5 inches in diameter and inflated with hydrogen gas to a diameter of about 15 in. They weigh from 8 to 12 grams each, and are given a free lift of 40 grams.

281. *Inflation device.*—The Brady free-lift device (fig. 59) is used for this purpose. This is placed on a table so that the rubber tubing rests thereon. The balloon is attached to the nozzle with two No. 17 rubber bands. These are doubled and placed around the neck of the balloon after it has been stretched over the nozzle. All the air should be expelled by opening the 3-way pet cock and rolling the balloon to force the air out of the pet cock. Inflation is then begun by slowly turning the hydrogen regulator handle to the right until a steady flow is maintained. The use of a hydrogen regulator is recommended for this work. The balloon should not be inflated in less than one minute. The gas is shut off as soon as the balloon lifts the nozzle from the table. If too much gas has been allowed to enter the balloon, the surplus may be expelled through the 3-way pet cock. To remove the balloon from the nozzle, the neck is twisted several times and secured with two No. 17 rubber bands, the latter being tightly wrapped by alternate twists and loops to insure a tight joint. Non-elastic cord should not be used for tying the necks of inflated balloons.

282. *Rate of ascent.*—A timepiece indicating seconds should be used. The average ascensional rate of these balloons, after being given a free lift of 40 grams, is 6 feet per second (180 ft. per half-minute). The average rate is somewhat greater, however, during the first one and one-half minutes, but becomes constant thereafter.

The following table shows the altitude of the balloon for every half minute for the first 8 minutes.

It will be noted that the rate of ascent is 250 feet for the first half minute, 190 feet for the second half-minute and 180 feet for each of the following successive half-minutes.

Time interval (min.)	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8
Altitude (feet)	250	480	670	850	1, 030	1, 210	1, 390	1, 570	1, 750	1, 930	2, 110	2, 290	2, 470	2, 650	2, 830	3, 010

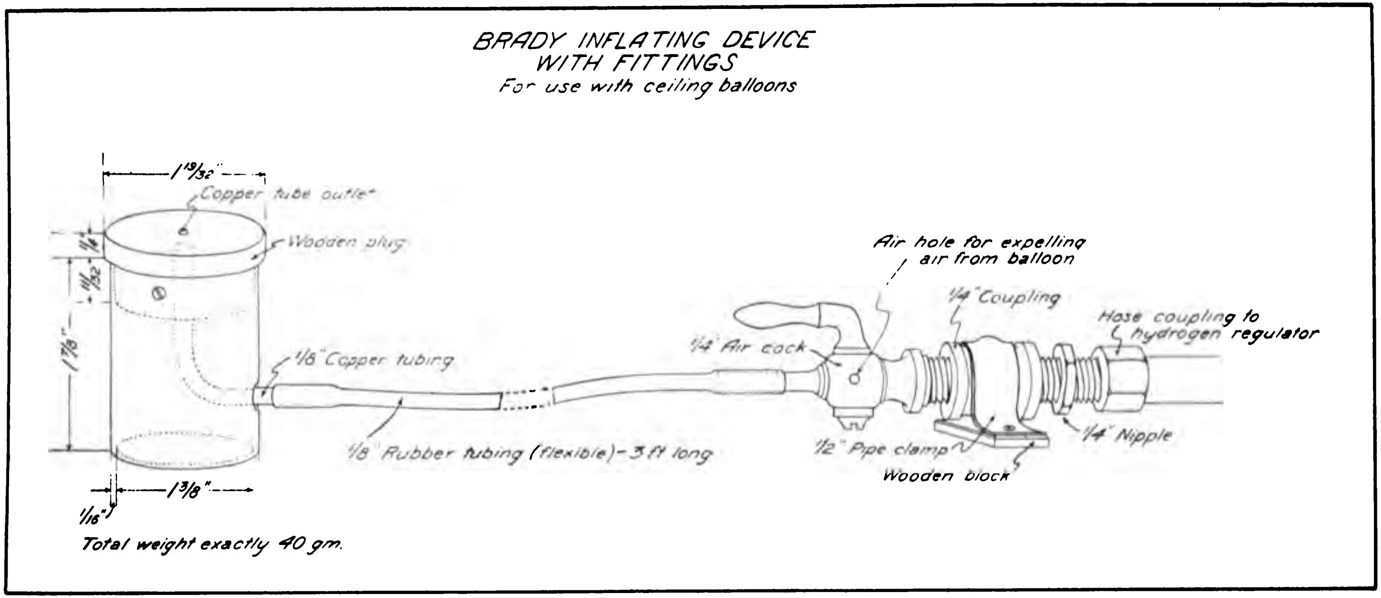


FIGURE 59. Brady free-lift device used for ceiling balloons

283. *Making the observation.*—The inflated balloon should be carried to a point free from obstructions, such as houses, trees, etc. It should be released on an exact minute and the eye should not be taken from it until it enters the clouds, at which instant the time should be noted. The height is then obtained from the table, making necessary interpolations for extra seconds over the last half-minute interval.

284. *Color of balloons.*—The balloons are usually furnished in two colors, viz, red and purple. In general, the darker color is best seen against a dark background.

285. *Danger of explosion.*—The same precautions given for the use of hydrogen in sounding balloon observations (Sec. XVII, par. 242) are necessary in this work.

286. The balloons should be kept in a cool, dark place, and never near any heated radiators, stoves, etc.

287. When reporting the ceiling, i. e., height of clouds, it must be remembered that some clouds have smooth bases and a balloon rising to them disappears abruptly when it enters their base. Other types have billowy and broken bases and when a balloon enters the base at one of the lower points of these billows it represents the ceiling more accurately than when it enters into a hollow or higher place in the cloud. Sometimes balloons drift into definite openings between the clouds and disappear. Such disappearances do not indicate the ceiling height, and in such cases, or if for any reason doubt exists as to the measurements obtained, another balloon should be released and the lower of the readings reported as the ceiling height.

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